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ANNUAL REPORT

OF THE

BOARD OF REGENTS

OF THE

SMITHSONIAN INSTITUTION,

SHOWING

THE OPERATIONS, EXPENDITURES, AND CONDITION OF THE INSTITUTION

FOR

THE YEAR 1874.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1875.

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FORTY-THIRD CONGRESS, SECOND SESSION.

CONGRESS OF THE UNITED STATES,
IN THE HOUSE OF REPRESENTATIVES,
February 27, 1875.

The following resolution, originating in the House of Representatives, February 24, 1875, has this day been concurred in by the Senate:

Resolved by the House of Representatives, (the Senate concurring,) That ten thousand five hundred copies of the report of the Smithsonian Institution for the year 1874 be printed, two thousand copies of which shall be for the use of the House of Representatives, one thousand for the use of the Senate, and seven thousand five hundred for the use of the Institution: *Provided,* That the aggregate number of pages of said report shall not exceed four hundred and fifty, and that there shall be no illustrations except those furnished by the Smithsonian Institution.

Attest:

EWD. McPHERSON, *Clerk.*

213621

LETTER

FROM THE

SECRETARY OF THE SMITHSONIAN INSTITUTION,

TRANSMITTING

The Annual Report of the Smithsonian Institution for the year 1874.

SMITHSONIAN INSTITUTION,
Washington, January 26, 1875.

GENTLEMEN: In behalf of the Board of Regents, I have the honor to submit to the Congress of the United States the annual report of the operations, expenditures, and condition of the Smithsonian Institution for the year 1874.

I have the honor to be, very respectfully, your obedient servant,

JOSEPH HENRY,
Secretary Smithsonian Institution.

Hon. HENRY WILSON,
President of the Senate.
Hon. J. G. BLAINE,
Speaker of the House of Representatives.

ANNUAL REPORT OF THE SMITHSONIAN INSTITUTION FOR 1874.

This document contains:

1. The annual report of the Secretary, giving an account of the operations and condition of the establishment for the year 1874, with the statistics of collections, exchanges, meteorology, &c.

2. The report of the executive committee, exhibiting the financial affairs of the Institution, including a statement of the Smithson fund, the receipts and expenditures for the year 1874, and the estimates for 1875.

3. The proceedings of the Board of Regents.

4. A general appendix, consisting principally of reports of lectures, translations from foreign journals of articles not generally accessible, but of interest to meteorologists, correspondents of the Institution, teachers, and others interested in the promotion of knowledge.

THE SMITHSONIAN INSTITUTION.

ULYSSES S. GRANT, President of the United States, *ex officio* Presiding Officer of the Institution.

MORRISON R. WAITE, Chief-Justice of the United States, Chancellor of the Institution, (President of the Board of Regents.)

JOSEPH HENRY, Secretary (or Director) of the Institution.

REGENTS OF THE INSTITUTION.

MORRISON R. WAITE, Chief-Justice of the United States, *President of the Board.*
HENRY WILSON, Vice-President of the United States.
H. HAMLIN, member of the Senate of the United States.
J. W. STEVENSON, member of the Senate of the United States.
A. A. SARGENT, member of the Senate of the United States.
S. S. COX, member of the House of Representatives.
E. R. HOAR, member of the House of Representatives.
G. W. HAZELTON, member of the House of Representatives.
JOHN MACLEAN, citizen of New Jersey.
PETER PARKER, citizen of Washington.
ASA GRAY, citizen of Massachusetts.
J. D. DANA, citizen of Connecticut.
HENRY COPPÉE, citizen of Pennsylvania.
GEORGE BANCROFT, citizen of Washington.

EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS.

PETER PARKER. **JOHN MACLEAN.** **GEO. BANCROFT.**

MEMBERS EX OFFICIO OF THE INSTITUTION.

U. S. GRANT, President of the United States.
HENRY WILSON, Vice-President of the United States.
M. R. WAITE, Chief-Justice of the United States.
H. FISH, Secretary of State.
B. H. BRISTOW, Secretary of the Treasury.
W. W. BELKNAP, Secretary of War.
G. M. ROBESON, Secretary of the Navy.
MARSHALL JEWELL, Postmaster-General.
C. DELANO, Secretary of the Interior.
GEO. H. WILLIAMS, Attorney-General.
J. M. THACHER, Commissioner of Patents.

OFFICERS AND ASSISTANTS OF THE INSTITUTION AND NATIONAL MUSEUM.

JOSEPH HENRY, Secretary, *Director of the Institution.*
SPENCER F. BAIRD, *Assistant Secretary.*
WILLIAM J. RHEES, *Chief Clerk.*
DANIEL LEECH, *Corresponding Clerk.*
CLARENCE B. YOUNG, *Book-keeper.*
HERMANN DIEBITSCH, *Exchange Clerk.*
JANE A. TURNER, *Exchange Clerk.*
MAGGIE E. GRIFFIN, *Recording Clerk.*
SOLOMON G. BROWN, *Transportation Clerk*

ASSISTANTS IN THE NATIONAL MUSEUM.

F. M. ENDLICH, *Mineralogist.*
ROBERT RIDGWAY, *Ornithologist.*
G. B. GOODE, *Zoologist.*
JOSEPH PALMER, *Taxidermist.*
T. W. SMILLIE, *Photographer.*
JOSEPH HERRON, *Janitor.*

RESIDENT COLLABORATORS.

Dr. THEODORE GILL, *General Zoology.*
Prof. F. B. MEEK, *Invertebrate Palæontology.*
Dr. E. COUES, *Mammalogy and Ornithology.*
W. H. DALL, *Malacology.*
Prof. O. T. MASON, *Ethnology.*
Prof. EDWARD FOREMAN, *Ethnology.*

REPORT OF THE SECRETARY, PROFESSOR HENRY, FOR THE YEAR 1874.

To the Board of Regents of the Smithsonian Institution:

GENTLEMEN: I have again the honor to present to you another annual report of the operations and condition of the Institution which the Congress of the United States has placed under your charge. During the period embraced in this report, that of the year 1874, nothing has happened to interfere with the prosecution of the plans which have been adopted for "the increase and diffusion of knowledge among men." The Institution, having now existed upward of twenty-five years, has established a character and reputation in the eyes of the world, the tradition of which will tend to perpetuate the same policy, with only such improvements as experience may suggest, notwithstanding the changes to which the *personnel* of the administration may from time to time be subjected.

The following changes have taken place in the Board of Regents during the year: Chief-Justice Waite has been elected Chancellor of the Institution, in place of Chief-Justice Chase, deceased. Prof. Asa Gray has been elected Regent by Congress in place of Prof. L. Agassiz; Prof. J. D. Dana, in place of Professor Woolsey; Prof. H. Coppee, in place of William B. Astor; Hon. A. A. Sargent, in place of Hon. Mr. Trumbull; Hon. E. R. Hoar, in place of Hon. James A. Garfield; Hon. G. W. Hazelton, in place of Hon. L. P. Poland; and Hon. George Bancroft, in place of General Sherman. The change in the government of the District leaves vacant, for the present, the position of Regent occupied by the governor of the District.

The resignation of General Sherman, on account of his change of residence to Saint Louis, Mo., leaves a vacancy in the executive committee. It gives me pleasure to present to the board, as an expression of his feelings toward the Institution, the accompanying letter.* It is proper to mention in this connection that during the interval between the death of Chief-Justice Chase and the appointment of his successor, Mr. Justice Clifford, of the Supreme Court, presided as Chancellor of the board, and with the Secretary signed the requisition for drawing the semi-annual interest from the Treasury of the United States on the 1st of January, 1874.

Since the establishment of the Institution several different bequests have been made, intended to increase its usefulness; but from none of these has anything as yet been realized, except from that of JAMES HAMILTON, Esq., of Carlisle, Pa., who bequeathed one thousand dollars to the Board of Regents of the Smithsonian Institution, the interest to be appropriated biennially for a contribution, paper, or lecture, on a scientific or useful subject. The money from this bequest has been received and placed in the Treasury of the United States, in accordance with the law of Congress authorizing the Secretary of the Treasury to receive any money which the Board of Regents may obtain from gifts, or savings of income, on the same terms as those of the original bequest. The first instalment of interest of the Hamilton bequest has just been received, and will be appropriated in accordance with the will of the testator at the end of next year, and so on continually at the end of every two years. A statement of the manner of expending this income will be given in the accounts of the operations of the Institution, with due credit to the donor. His name will therefore appear from time to time in the annual reports, and thus be kept in perpetual remembrance.

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* See proceedings of the Board of Regents.

When the public shall become more familiar with the manner in which the income of the additional bequests to the Smithson fund is expended, with the permanence and security of the investment, and with the means thus afforded of advancing science, and of perpetuating the names of the testators, we doubt not that additions to the fund in this way will be made until it reaches the limit prescribed by law of one million dollars.

Since the establishment of the Institution great change has taken place in the public mind as to the appreciation of the importance of abstract science as an element in the advance of modern civilization. At the time the bequest of Smithson was made the distinction between original research and educational instruction in science and literature was scarcely recognized. As an evidence of this it may be stated that, in answer to a circular-letter addressed to a number of the most distinguished writers in this country, asking what should be done with a fund intended to increase and diffuse knowledge among men, the unanimous reply was, "Establish a national university;" the idea of a university being at that time an institution simply intended to drill youth in the ancient classics, in the elements of mathematics and physical and moral science. The idea of an institution intended for the higher object of increasing knowledge, or enlarging the bounds of human thought by original research, had not dawned at that time upon the mind of the general public, and the plan proposed for realizing this idea was violently opposed by some of the most intelligent and influential men of the country. Happily, since then a great change has been effected both in this country and in Europe, and to effect this change the persistent policy of the Institution has contributed in no inconsiderable degree. The plan adopted of applying the income as far as possible to the promotion of original research and the distribution of a knowledge of the results through its publications, has received the approval of the civilized world. The Congress of the United States has fully signified its appreciation of the plan adopted, by relieving the Institution from the support of a library and the National Museum.

Congress having made an appropriation of $20,000 for the support of the National Museum, almost the entire income of the Smithson bequest has been left free to carry on what is now considered the legitimate operations of the Institution. It was thought, however, desirable to retain a part of the income in order to make up the loss of last year, occasioned by the failure of the First National Bank of Washington. The whole amount of deposit in this bank at the time mentioned was $8,224.87. On this the Institution has received 50 per cent., in two payments, leaving a balance of $4,112.43. Toward making up this loss, the expenditure during the year has been less than the receipts by $3,683.31. The funds of the Institution are therefore in a favorable condition, as may be seen by the exhibit hereafter to be presented.

FINANCES.

The following is a statement of the condition of the funds at the beginning of the year 1875:

The amount originally received as the bequest of James Smithson, of England, deposited in the Treasury of the United States in accordance with the act of Congress of August 10, 1846	$515, 169 00
The residuary legacy of Smithson, received in 1865, deposited in the Treasury of the United States, in accordance with the act of Congress of February 8, 1867	26, 210 63
Total bequest of Smithson	541, 379 63
Amount deposited in the Treasury of the United States, as authorized by act of Congress of February 8, 1867, derived from savings of income and increase in value of investments	108, 620 37
Amount received as the bequest of James Hamilton, of Carlisle, Pa., February 24, 1874	1, 000 00
Total permanent Smithson fund in the Treasury of the United States, bearing interest at 6 per cent., payable semi-annually in gold	651, 000 00
In addition to the above there remains of the extra fund from savings, &c., in Virginia bonds and certificates, viz: consolidated bonds, $58,700; deferred certificates, $29,375.07; fractional certificate, $50.13; total $88,125.20, now valued at	35, 000 00
Cash balance in United States Treasury at the beginning of the year 1875 for current expenses	15, 909 99
Amount due from First National Bank, Washington, $4,112.43, (present value unknown.)	
Total Smithson funds January, 1875	$701, 909 99

On comparing this statement with that made last January, it appears that the total amount of the fund has been increased during the year $6,683.31, viz:

By the Hamilton bequest	$1,000 00
By the increased value of Virginia stock	2,000 00
By balance of unexpended annual income	3,683 31
	$6,683 31

The Board of Regents and the Secretary will in future be relieved of all anxiety as to the safety of the semi-annual interest by the arrangement which has been made with the United States Treasurer to receive it as a deposit, and to make payments from it on checks of the Secretary, in the same manner as has been done heretofore in the First National Bank.

The Institution is indebted to General Spinner for his prompt acquiescence in the proposition and for immediately carrying it out in all the details necessary to facilitate its operation.

Congress, at its last session, made an appropriation of $20,000 for the care and preservation of the specimens in the museum, and $10,000 for fitting up apartments in which the specimens are exhibited.

The uncollected coupons on the Virginia bonds held by the Institution were sold on the 9th of May, 1874, by Riggs & Co., with the following result:

$1,200 Virginia coupons at 77⅛	$925 50
$2,322 Virginia coupons at 77	1,787 94
	2,713 44
Less charges	17 61
	$2,695 83

This amount was deposited with the Treasurer of the United States to the credit of the account of the current expenses of the Institution for the year.

PUBLICATIONS.

Since the reports of the Institution are separately distributed to many persons who have not ready access to the whole series, it is necessary in each succeeding one to repeat certain facts which may serve to give an idea of the general organization of the establishment. The following statement is therefore repeated:

The publications of the Institution are of three classes, viz, the CONTRIBUTIONS to KNOWLEDGE, the MISCELLANEOUS COLLECTIONS, and the ANNUAL REPORTS. The first consist of memoirs containing positive additions to science resting on original research, and which are generally the result of investigations to which the Institution has, in some way, rendered assistance. The Miscellaneous Collections are composed of works intended to facilitate the study of branches of natural history, meteorology, &c., and are designed especially to induce individuals to engage in these studies as specialties. The Annual Reports, besides an account of the operations, expenditures, and condition of the Institution, contain translations from works not generally accessible to American students, reports of lectures, extracts from correspondence, &c.

The following are the rules which have been adopted for the distribution of the several publications of the Institution:

1st. They are presented to learned societies of the first class which in return give complete series of their publications to the Institution.

2d. To libraries of the first class which give in exchange their catalogues and other publications, or an equivalent from their duplicate volumes.

3d. To colleges of the first class which furnish catalogues of their libraries and of their students, and all other publications relative to their organization and history.

4th. To States and Territories, provided they give in return copies of all documents published under their authority.

5th. To public libraries in this country, containing 15,000 volumes, especially if no other copies are given in the same place; and to smaller libraries where a large district would be otherwise unsupplied.

6th. To institutions devoted exclusively to the promotion of particular branches of knowledge are given such Smithsonian publications as relate to their respective objects.

7th. The Annual Reports are presented to the meteorological observers, to contributors of valuable material to the library or collections, and to persons engaged in special scientific research.

The distribution of the publications of the Institution is a matter which requires much care and judicious selection, the great object being to make known to the world the truths which may result from the expenditure of the Smithson fund. For this purpose the principal class of publications, namely, the Contributions, must be so distributed as to be accessible to the greatest number of readers, and this will evidently be to large central libraries.

The volumes of Contributions are presented on the express condition that, while they are carefully preserved, they shall be accessible at all times to students and others who may desire to consult them, and be returned to the Institution in case the establishments to which they are presented at any time cease to exist. These works, it must be recollected, are not of a popular character, but require profound study to fully understand them; they are, however, of importance to the professional teacher and the popular expounder of science. They contain materials from which general treatises on special subjects may be elaborated.

Full sets of the publications cannot be given to all who apply for them, since this is impossible with the limited income of the Institution; and, indeed, if care be not exercised in the distribution, so large a portion of the income would be annually expended on the production of copies for distribution of what has already been published, that nothing further could be done in the way of new publications. It must be recollected that every addition to the list of distribution not only involves the giving of publications that have already been made, but also those which are to be made hereafter.

At the commencement of the operations of the Institution the publications were not stereotyped, and consequently the earlier volumes have now become scarce, especially the *first*, of which there are now no copies for distribution, although it can occasionally be obtained at a second-hand book-store in one of the larger cities.

No copyright has ever been secured on any of the publications of the Institution. They are left free to be used by compilers of books, with the understanding, however, that full credit will be given to the name of Smithson for any extracts which may be made from them. This condition is especially insisted on, because the credit thus required is important as evidence to the world of the proper management of the Smithson fund. In many cases credit is given merely to the author without mentioning the name of the Institution; this is not just, since, as a general rule, the income of the establishment is applied not only to the publication of the article but also to assist in its production.

Publications in 1874.—During the past year the *nineteenth* volume of the quarto series of the Smithsonian Contributions to Knowledge has been published. It contains the following papers:

1. Problems of Rotary Motion presented by the Gyroscope, the Precession of the Equinoxes, and the Pendulum. By Brevet Maj. Gen. J. G. Barnard. 4to., pp. 74.
2. A Contribution to the History of the Fresh-Water Algæ of North America. By Horatio C. Wood, jr., M. D., professor of botany and clinical lecturer on diseases of the nervous system in the University of Pennsylvania. 4to., pp. 274, 21 colored plates.
3. An Investigation of the Orbit of Uranus, with General Tables on its Motion. By Simon Newcomb, professor of mathematics, United States Navy. 4to., pp. 296.

This volume, of which the several memoirs have been described in previous reports, will not only sustain, but increase the reputation of the Institution for its contributions to the science of the day. The memoirs which it contains have been received with manifest interest by the scientific world, and recognized as positive additions to knowledge resting on original investigation.

Besides the nineteenth volume of the Contributions to Knowledge, the *eleventh* and *twelfth* volumes of Miscellaneous Collections have been published during the year.

The *eleventh* volume of Miscellaneous Collections consists of 789 octavo pages, and contains the following articles:

1. Arrangement of the Families of Mammals, with Analytical Tables. Prepared for the Smithsonian Institution by Theodore Gill, M. D., Ph. D., pp. 104.

2. Arrangement of the Families of Fishes, or classes Pisces, Marsipobranchii, and Leptocardii. Prepared for the Smithsonian Institution by Theodore Gill, M. D., Ph. D., pp. 96.

3. Monographs of the Diptera of North America; Part III, Ortalidæ Family. Prepared for the Smithsonian Institution by H. Loew; four plates, pp. 376.

4. Directions for collecting and preserving Insects. Prepared for the use of the Smithsonian Institution by A. S. Packard, jr., M. D., pp. 60.

5. New Species of North American Coleoptera. Prepared for the Smithsonian Institution by John L. LeConte, M. D.; Part II, pp. 74.

6. Classification of the Coleoptera of North America. Prepared for the Smithsonian Institution by John L. LeConte, M. D., pp. 72.

The *twelfth* volume of Miscellaneous Collections consists of 767 octavo pages, and contains the following articles:

1. Review of American Birds, in the Museum of the Smithsonian Institution; Part I. By S. F. Baird, 1864–1872, pp. 484.

2. The Constants of Nature; Part I. Specific Gravities; Boiling and Melting Points; and Chemical Formulæ. Compiled by F. Wigglesworth Clarke, S. B. December, 1873, pp. 272.

3. Rules for the Telegraphic Announcements of Astronomical Discoveries. By Prof. Joseph Henry. April, 1873, pp. 4.

Since the publication of the 19th volume of Smithsonian Contributions, a memoir, of 32 quarto pages, has been printed and distributed, which will form part of the 20th volume. This is by Prof. S. Newcomb, of the National Observatory, Washington, on the "General Integrals of Planetary Motion"—an abstruse mathematical work, of which the nature is indicated in its title. It gives a series of suggestions and new investigations relative to the methods of determining the motions of celestial bodies as affected by interplanetary perturbations. It is in part an extension and generalization of two former papers by the same author, the first published in Liouville's Journal, vol. XVI, 1871, and the second in the Comptes-Rendus, vol. LXXV. It was submitted to Prof. H. A. Newton, of Yale College, and Mr. G. W. Hill, of Nyack, N. Y., for critical examination, and received their unqualified approval for publication in the Smithsonian Contributions to Knowledge.

Another paper, intended for the twentieth volume of Contributions, which has been printed and distributed during the past year, is by James G. Swan, on the Haidah Indians of Queen Charlotte Islands. It consists of 18 quarto pages, and is illustrated with five plain and two colored plates, to represent the carved posts or pillars raised in front of the houses of the chiefs, and various tattoo designs copied from the bodies of the Indians. This paper was described in the last report. It may, however, be here mentioned that it is of special interest in connection with the large number of ethnological specimens received during the past year from the northwest coast.

Another work published during the year is the third of the Toner-lecture series. It is by Dr. J. M. DaCosta, of Philadelphia, on the strain and over-action of the heart, and forms 32 octavo pages, illustrated by two wood-cuts. These lectures, as has been stated in previous reports, have been instituted at Washington by Dr. Joseph M. Toner, and are confined to such memoirs or essays relative to medical science as contain some new truth fully established by experiment or observation. It is proper to remark that of this course of lectures only two have been published, the first and the third, the author having not yet furnished the manuscript of the second. To defray, in part at least, the cost of printing these lectures, it has been thought advisable to charge for them 25 cents a copy to individuals who have no special claim on the Institution by having contributed meteorological observations or additions to the collections.

Another work printed during the year is a list of the publications of the Institution to July, 1874, exhibiting 297 distinct articles, arranged first numerically, and secondly in regard to the subjects as given in the titles. It forms an octavo of 26 pages. An edition of 2,500 copies of this work was furnished to the "Publishers' Trade-List Annual" for 1874, (New York, October, 1874,) and through this medium the list of publications of the Institution will become known to all booksellers and librarians in the United States.

An edition of 250 copies of tables selected from the volume of Physical and Meteorological Tables, prepared and published some years since at the expense of the Institution, has been printed for the use of the Argentine Meteorological Observatory at Cordoba, under the direction of our distinguished countryman, Dr. B. A. Gould.

Publications in the press: 1. The Antiquities of Tennessee, by Dr. Joseph Jones, of which an account was given in the last report. Of this the wood-cuts have been prepared, and it is expected that the printing will be finished in the course of the present year.

2. A Memoir on the Harmonies of the Solar System, by Prof. Stephen Alexander, of the College of New Jersey.

In this communication the author divides his subject into three sections. Section I begins with the statement that Kepler's third law is ordinarily expressed by saying that the squares of the periodic times of the several planets of the solar system are to one another, respectively, as the cubes of their distances from the sun; but from this we do not learn that there are any laws determining the ratios of the distances themselves, and it is one of the main objects of the present discussion to show that such laws exist, and precisely what they are; generality and precision being characteristics of every law of nature.

The author discusses anew the expressed values of the distances in question, in view of the fact that Kepler's third law is itself slightly modified by the consideration due to the *masses* of the revolving bodies. After an exhibition and discussion of the appropriate formula, the author arranges the results in the form of a table; in which the results thus shown are respectively consistent with two values of the solar parallax, viz, Professor Newcomb's value, $\pi = 8''.848$, and that which others prefer, $\pi = 8''.78$.

Section II exhibits the laws of arrangement of the distances, both of planets and their satellites, from their respective centers of attraction, without the introduction in the same connection of any physical hypothesis on which those laws seem to be founded or of which they are the exponents.

From a comparison of the several distances of the planets, taking five-ninths of the distance of Neptune from the center of attraction and five-ninths of this product, &c., he finds among the several terms of the geometrical series thus formed, those which represent the relative distance of Saturn and Jupiter, also a position among the asteroids and those which represent the distance of Mars, and of Mercury in aphelion. There are, however, in the geometrical series just mentioned, terms which do not find their correspondences in the series of distances of the planets, but which the author very ingeniously supplies by attributing to certain of the planets the characteristic of half planets, the term pertaining to them being indicative of the distance between the two planets at which their masses would be united.

Section III exhibits an explanation of the phenomena founded on the nebular hypothesis of La Place, which seems to reconcile and account for the laws in question as well as a number of other phenomena.

Approximation to these laws have, from time to time, been exhibited by the author of this paper to the American Association for the Advancement of Science at several of its meetings, beginning with that at New Haven, in 1850; but it is only within the past few months that the entire form and consistency of the results have been quite fully made out. The principal part of the memoir was read before the National Academy of Sciences at its meeting in April, 1873, and some additional portions of the same at the meeting in April, 1874. In accordance with usage in such cases, the work was accepted for publication in the Smithsonian Contributions to Knowledge.

3. The Winds of the Globe, by the late Prof. J. H. Coffin, prepared at the expense of the Institution, relative to which further information will be given under the head of meteorology. Of this, 250 quarto pages have been stereotyped, and the whole work, which will form an entire volume of the Smithsonian Contributions to Knowledge, will be published during the year 1875.

4. The Temperature-Tables of the North American Continent, prepared

at the expense of the Institution, under the direction of Mr. C. A. Schott. Of this, 100 pages have been stereotyped.

Of the octavo publications there are in press:

1. The monograph on the American *Vespidæ* or wasps, by Professor de Saussure, of Geneva. Of this a full account was given in the last report. The rapidity of printing in this case is diminished by the necessity of sending the proof-sheets to Switzerland. The work has been stereotyped as far as the 236th page, and we trust will be completed in the course of a few months.

The Botanical Index, of which a notice was given in the Report for 1870, has been commenced, and 72 pages printed. This work is a complete index to all the species of plants of North America, with their synonyms, and all descriptions and important references to them. It is intended to facilitate the labors of working botanists, especially in the study of our western plants, the search for what has been written in regard to them requiring in many cases nearly as much time and labor as all the rest of their work.

As a further contribution to the "Constants of Nature" mentioned in the last report, Prof. F. W. Clarke has furnished an additional series of tables of specific heat and of expansion by heat for solids and liquids. We have also received from our collaborator, Prof. John L. LeConte, of the University of California, a series of constants relative to the weight of air, pressure of the atmosphere, length of seconds, pendulum-velocity generated by gravity in a mean solar second of time at various places, velocity of sound, &c. It is the intention of the Institution to continue this work, and to endeavor to enlist other co-laborers in its prosecution.

RESEARCHES.

Meteorology.—It was stated in the last report that the meteorological system of records by voluntary observers, which had been in operation under the direction of the Institution for about twenty-five years, had been transferred to the signal-office of the War Department, under General A. J. Myer. This transfer was made in accordance with the general policy of the Institution, namely, that of abandoning any field of enterprise as soon as the work could be done as well through other agencies, thus reserving the energy of the establishment for labors which required more aid in their accomplishment. We think this transfer has received the approbation of observers generally; who also, while they are now co-operating with the Signal-Service, still keep up their correspondence with the Institution on subjects of general scientific interest. The labors of the Institution in the line of meteorology are now confined to working up the material which it has collected during the last quarter of a century. The materials, however, are not limited to that period, but embrace everything that could be obtained on the subject from the records of previous observers.

The first work of this class which has been published is that of the the Rain-fall. It included all the material which had been collected down to 1866. It is now proposed to publish a new edition of this work, containing the additions since made, with improved maps, on a larger scale.

The next work of the same class is that on the Winds of the Globe, comprising the result of the discussion of not only the observations made under the direction of the Smithsonian Institution in the United States, but of those of every other part of the world of which the records were attainable. This work, to which the labors of Prof. J. H. Coffin, of Lafayette College, were for many years devoted, was nearly completed at the time of his death, has been continued by his son, Prof. Selden J. Coffin, and is now in the press. Very little, however, was done by the elder Coffin in the way of stating, in general propositions, the results contained in the large number of tables which he had elaborated. To supply this deficiency the Institution has fortunately been enabled to avail itself of the assistance of Dr. A. Woeikof, member of the Geographical Society of Russia, and late secretary of its meteorological commission, who, visiting this country for the study of its climatology, cheerfully undertook the required task.

The printing of this work is very expensive. It will occupy an entire volume of the Smithsonian Contributions, and comprise upward of 600 quarto pages of tabular matter, besides the letter-press. It will, however, we are confident, form a contribution to knowledge which will be a lasting monument to the industry of Professor Coffin and to the policy of the Smithsonian Institution.

The next work of the same class is that on the Temperature of the United States. It has been in progress at the expense of the Institution for a number of years. It includes the result of the discussion of all the observations which have been made in this country from the earliest times down to the present. It is illustrated by three maps of isothermal spaces—one exhibiting the annual, another the summer, and the third the winter distribution of temperature—and a number of diagrams incorporated in the text. It has been from the first under the direction of Prof. Charles A. Schott, of the Coast Survey, assisted by a number of computors, at the expense of the Smithson fund. The maps have been drawn and are in the hands of the engraver, and the whole work will be printed and distributed during the present year. It will form the first trustworthy approximation to an exhibition of the temperature of the various portions of the United States which has ever been published. The preparation of it has been more expensive than any other work ever undertaken by the Institution.

Another work in progress is that relative to the geographical distribution in the United States of thunder-storms, the frequency of their occurrence in different seasons, and effects produced by discharges of lightning, as compiled from all the records of the Institution during twenty-five years. The preliminary labor was the collection and arrangement of a full list of stations at which thunder-storms have been recorded, the number of observations at each place, the time of beginning and ending of each storm, and the whole number of thunder-storms occurring in each year, and during the whole time at each place. From these data the relative frequency of thunder-storms in different parts of the country can be determined; also their relative frequency in different seasons and years, as well as the extent of the area over which they occur on the same day. The attending casualties, collected from all the observations made by several hundred observers during a period of twenty-five years, when brought together and classified, will strikingly illustrate the operations of one of the most energetic agents of nature.

For the preliminary arrangement of the materials preparatory to scientific deductions from them, the Institution has employed Mr. George H. Boehmer.

Another series of reductions relative to the meteorology of North America which will occupy the attention of the Institution is that of the discussion of the observations on the barometer in various parts of the United States. This will be commenced as soon as the other series of investigations are completed.

Comets.—The first research relative to these I have to mention is that relative to a comet of short period or one that returns after a few years. Of these, there are at present six known, namely, Encke's, which has a period of about 3½ years; Winnecke's, of between 5 and 6 years; Biela's, of 6¾ years; Faye's, of 7½ years; Tuttle's, of 13$\frac{7}{10}$ years; and Halley's, of about 76 years.

All the other comets which have entered the solar system have never been known to return, their orbits having probably, in many cases, been changed by the perturbations of planets in whose vicinity they may have passed.

The motion of the periodical comets is an object of great interest to the astronomer, as well as to the general physicist, in its relation to the question of the existence of a retarding medium filling interplanetary spaces, and therefore it is considered an object of much importance, not only to observe their successive positions at their periodic returns, but also to calculate with great precision their orbits as affected by planetary perturbations. At a meeting of European astronomers in August, 1873, the work of discussing all the observations which have been made on four of these comets was parceled out among the continental astronomers, Halley's comet having previously received great attention from the English and other astronomers; and the fifth, that of Tuttle, discovered by an American astronomer, was left to be worked out in this country. This task has been undertaken at the expense of the Smithsonian Institution, under the direction of Prof. Ormond Stone, late of the National Observatory, and now professor of astronomy in the

University of Cincinnati. Professor Stone has chosen for this work a number of assistants, and will proceed with the reduction and discussion of the observations made on this comet at its several returns as rapidly as his other labors will permit.

The perturbations of the first order have been calculated, and the zero stars used in determining the place of the comet at the time of its last return in 1871 have been re-observed with the Washington meridian circle. An accurate determination of the orbit traversed by this comet in 1871, as based on the corrected position of these stars, has been in part completed.

In this connection it may be interesting to state that of the one hundred and forty* asteroids discovered during this century, forty-two were first observed by American astronomers. It is not enough, however, that these bodies should be noted as planets, and their positions marked in the heavens for a given epoch; it is also necessary that their orbits should be accurately determined, and an ephemeris of each of them calculated by which its place can be ascertained at any future time. This work, however, is one, as it were, of approximation, and must be continued through a series of revolutions of each planet. In regard to the asteroids discovered in Europe, the investigation of them is under the charge of European astronomers; while for the investigation of those discovered in America, Congress has made an appropriation for the last three years, to be expended under the direction of Professor Coffin, director of the American Nautical Almanac.

Efficiency of steam-heaters.—Another investigation, at the partial expense of the Smithsonian Institution, has been undertaken under the direction of General W. B. Franklin, late of the United States Army, at the Colt's Fire-Arms Manufacturing Company, Hartford, Conn., by Mr. C. B. Richards, of which the following is an account:

The experiments which are proposed will be in continuation of two series already made, to ascertain the relative efficiency of the different kinds of steam-heaters used for warming buildings, and to determine also the laws of their operation. The first series related to what are known as "direct radiators," and in these the heaters were exposed in a large room whose temperature could be changed and regulated as desired. In the second series the heaters were of the kind called "indirect radiators," and were inclosed in a flue through which currents of air were passed. The initial and final temperatures, the barometric pressure, and the moisture of the air were noted, and the quantity passed through the flue was measured by a Casella meter.

In both series the pressure of the steam was measured by an accurate mercury column, and its temperature was noted, while the heating effect of the heater was calculated from data obtained by collecting, cooling, and weighing the water of condensation obtained from the steam which was passed through the heater.

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* Since the above was written two additional asteroids have been discovered.

Very satisfactory and consistent results were arrived at from the first series. But in the second series, the cost of the apparatus, the many different circumstances which it was necessary to take into account, the consequent greater care and time required in the investigation, and a lack of money with which to pursue the inquiry to the proper point, prevented the establishment of trustworthy data.

The importance of deciding the questions which it is the specific object of these experiments to answer need not be urged. There is, however, one interesting circumstance which, among others, was observed, and which may be of importance outside the principal question. This relates to the determination of the condition of the steam as regards its dryness when it entered the heating apparatus; and, as a small quantity of steam was occasionally allowed to escape after it had passed through the heater, (in order to carry off air,) it was also desirable to ascertain whether any very considerable amount of water, in the condition of mist, was carried away by this escaping steam.

Hirn's method was employed in these determinations. Although the apparatus for this purpose was crude, and for precise experiments would require to be much improved, the experiments seemed to indicate clearly that the steam was nearly if not quite as dry, after passing over the condensing surface of the heater, as before; that is to say, its "mistiness" was not increased by its passage over a large extent of condensing surface. These results, if fully verified by a longer series of experiments with better apparatus, would indicate that there is a fallacy in the generally-entertained idea that "wet steam" is supplied to an engine if the originally dry steam is led through a long pipe.

The records of the experiments are voluminous, and it is intended to tabulate them, and to represent the results by curves when the whole are completed.

Elevations.—It has been mentioned in previous reports that the Institution has been at considerable expense in collecting the profiles of canal, railroad, and other surveys, in order to the construction of a topographical map of the United States. The charge of this work was given to Mr. Nicholson, topographer to the Post-Office Department, but, owing to the absorbing nature of his official duties, he has been unable up to this time to complete it. In the mean while Mr. Gardner, of the Hayden expedition, has rendered an important service to this investigation by settling, through critical comparison of various surveys, the actual height of several important places in the interior, which will hereafter serve as points of departure for other surveys.

Natural History and Ethnology.—Various researches have been made in natural history and ethnology, the actual expense of which has been defrayed by the Institution, without salary, however, to the person in charge of the work; an account of which will be given in a subsequent part of the report.

INTERNATIONAL EXCHANGES.

The Smithsonian system of international exchange still continues to render an important service to the advance of civilization, and emphatically to carry out the second clause of the will of Smithson for the increase and diffusion of knowledge among men—that is, mankind. It is the medium of exchange of literary and scientific materials between the United States and all foreign countries.

The effect of this system on the diffusion of knowledge can scarcely be too highly estimated. Thousands of works, containing the details of the latest inventions and discoveries, are through its means annually brought to this country, while a knowledge through the same medium is disseminated abroad of everything that is doing in the United States to promote a higher civilization.

As an evidence of the high estimation in which this part of the operations of the Institution is regarded, we may again mention that the Smithsonian packages are passed through all the custom-houses of the world free of duty and without examination, and, moreover, that they are transmitted free of cost by the principal transportation companies, namely:

Pacific Mail Steamship Company.
Panama Railroad Company.
Pacific Steam Navigation Company.
New York and Mexico Steamship Company.
New York and Brazil Steamship Company.
North German Lloyd Steamship Company.
Hamburg American Packet Company.
French Transatlantic Company.
North Baltic Lloyd Steamship Company.
Inman Steamship Company.
Cunard Steamship Company.
Anchor Steamship Company.

The special thanks of the Institution are again due to the above-mentioned companies for their enlightened liberality.

The following are the foreign centers of reception and distribution of the Smithsonian exchanges:

London—Agent, William Wesley, 28 Essex street, Strand.
Paris—G. Bossange, 16 rue du 4 Septembre.
Leipsic—Dr. Felix Flügel, 12 Sidonien Strasse.
St. Petersburg—L. Watkins & Co., 10 Admiralty Place.
Amsterdam—F. Müller.
Milan—U. Hoepli, 591 Galeria Cristoforia.
Harlem—Prof. Baumhauer.
Christiana—Royal University of Norway.
Stockholm—Royal Swedish Academy of Sciences.
Copenhagen—Royal Danish Society.

The following table exhibits the number of foreign establishments with which the Institution is at present in correspondence, or, in other words, to which it sends publications and from which it receives others in return:

Number of Foreign Corresponding Institutions.

Sweden	20	Belgium	110
Norway	24	France	274
Iceland	2	Italy	169
Denmark	27	Portugal	20
Russia	160	Spain	12
Holland	65	Great Britain and Ireland	357
Germany	622	South America	40
Greece	7	West Indies	7
Turkey	11	Mexico	10
Africa	23	Central America	1
Asia	42	British America	27
Australia	27	General	5
New Zealand	13		
Polynesia	2	Total	2,146
Switzerland	69		

The table in itself is interesting as indicating the relative attention given to literature and science at the present day in the different countries of the world.

During the past year 4,326 packages, each containing several articles, have been received from abroad for distribution to institutions and individuals in this country.

One hundred and forty-one boxes, averaging 7 cubic feet each, with a total weight of 29,600 pounds, were sent abroad by the Institution during the year, viz: To Germany, 40; England, 30; Sweden, 5; Norway, 3; Denmark and Iceland, 4; France, 11; Russia, 7; Holland, 5; Belgium, 5; Australia, 11; Italy, 3; Cuba, 2; Brazil, 3; Liberia, 1; Egypt, 1; Canada, 10.

The total number of separate parcels contained in these boxes was about 10,000.

To facilitate the business of the exchanges, the following rules have been adopted:

1. Every package, without exception, must be enveloped in strong paper, and secured so as to bear separate transportation by express or otherwise.

2. The address of the institution or individual, for whom the package is intended, must be written legibly on the cover, and the name of the sender on one corner of the same.

3. No single package must exceed the half of a cubic foot in bulk.

4. A detailed list of addresses of all the parcels sent, with their contents, must accompany them.

5. No letter or other communication can be allowed in the parcel, excepting such as relates exclusively to the contents of the package.

6. All packages must be delivered in Washington free of freight and other expenses.

7. Every parcel should contain a blank acknowledgment, to be signed and returned, either through the agent of the Institution, or, what is still better, through the mail, to the sender. Should exchanges be desired for what is sent, the fact should be explicitly stated on the list of the contents of the package. Much disappointment is frequently expressed at the absence of any return in kind for transmissions; but un-

less these are specifically asked for they will fail in many instances to be made. It will facilitate the labors of the Institution very greatly if the number corresponding to the several addresses in the Smithsonian printed catalogue* be marked on the face of each parcel; and for this purpose a copy of the catalogue will be forwarded to all who apply for it.

Specimens of natural history will not be received for transmission unless with a previous understanding as to their character and bulk.

8. Unless all these conditions are complied with the parcels will not be forwarded from the Institution; and, on the failure to comply with the first and second conditions, will be returned to the sender for correction.

The operations of the system of exchange have increased from year to year, and notwithstanding the liberal assistance received from transportation companies, it now absorbs nearly a seventh part of the entire income of the establishment. In order to improve its efficiency and the frequency of transmission of packages, a larger proportion of the income will be required. In view of these facts, the Secretary at the last session of the Board of Regents was authorized to receive aid from societies and individuals in defraying the heavy expense of this part of the operations of the Institution.

Miss Jane Turner, sister of the late Prof. W. W. Turner, the well-known philologist, continues to have charge of receiving and cataloguing the exchanges intended for the library of the Institution, and of distributing those for other parties.

The receiving, packing, and shipping of the packages from different parts of the United States intended for foreign countries, is under the charge of Mr. H. Diebitsch.

LIBRARY.

In 1866, the library of the Institution was incorporated with that of Congress. This arrangement is still continued, and is beneficial to both establishments. The Smithson fund is relieved from the maintenance of a separate library, while at the same time the Institution has the use not only of its own books but of those of the Library of Congress. On the other hand, the Library of Congress is enriched by an entire department, that of books relating to modern science.

The following is a statement of the books, maps, and charts received by exchange in 1874:

Volumes:		
Octavo, or less	657	
Quarto, or larger	206	
		863

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* Miscellaneous Collections, No. 243.

Parts of volumes:		
Octavo, or less	1,607	
Quarto, or larger	1,359	
		2,966
Pamphlets:		
Octavo, or less	1,962	
Quarto, or larger	593	
		1,555
Maps and charts		162
Total receipts		5,546

Among the principal donations received in 1874, are the following:

From the Company of Public Works of the Mediterranean: "Bassins de Radoub de Marseille. Notice sur l'exécution des travaux," with an atlas of 40 plates, (2 copies.)

From the Argentine Confederation: "Description géographique et statistique de la Confédération Argentine, par V. de Moussy," vols. i–iii, with folio atlas.

From the National Hungarian Museum, Buda-Pesth: "Monuments épigraphiques du Musée National Hongrois, dessinés par Ernest Desjardins," 1 vol., folio, Buda-Pesth, 1873.

From the Imperial Archæological Commission, St. Petersburg: "Compte-rendu de la Commission Impériale Archéologique," for 1870 and 1871, with folio atlas.

From the Icelandic Literary Society, "Reykjavik Skirnir," 1874: "Skyrsla um Forngripasafu Islands i Reykjavik," vols. i, ii, 1863–1870. Copenhagen, 1868, 1874. "Fyettir fra Islandi," 1873. Reykjavik, 1874, 8vo.

From the Universities of Berlin, Bonn, Erlangen, Freiberg, Göttingen, Greifswald, Halle, Jena, Leipzig, Marburg, Rostock, Würzburg, Basel, Bern, and Zurich: Inaugural Dissertations for 1873.

From the Hydrographic Department of the Ministry of Marine, St. Petersburg; 23 charts, 10 volumes, and 6 pamphlets.

From the Veterinary School, Dorpat, 48 pamphlets.

From the British Museum, London, "Catalogue of Greek Coins, Italy," 1873, 8vo.; "Catalogue of Roman Coins in the British Museum, Roman Medallions," 1874, 4to.; "Catalogue of Prints and Drawings," Division I. "Political and Political Satires," vol. ii., 1869–1873, 8vo.; "Fac-similes of Ancient Characters," 1873, folio; "Catalogue of Birds," vol. i, 1874, 8vo.; "Hand-List of Seals, Morses, Sea-Lions, etc.," 1874, 8vo.; "Hemiptera, Heteroptera," vol. viii, 1873, 8vo.; and various guide-books.

From the Board of Admiralty, London, 28 charts published by the Hydrographic Office, from January, 1873, to January, 1874; "The China Sea Directory," vol. iv; "The Mediterranean Pilot," vol. i; "Red Sea Pilot," 1873; "Tide-Tables," 1874; "Nautical Almanac for 1878;" and 10 lists of lights.

From the Overijssel Society for the Promotion of Provincial Welfare, Zwolle, 8 volumes, 8 parts, and 5 pamphlets.

From the Royal Statistical Bureau, Copenhagen, "Statistisk Tabelvoerk," vols. xx–xxvi, (2 copies;) "Sammendrug," etc., 10 parts.

From Messrs. Robert and Alexander Stuart, New York, "Anti-Nicene Christian Library; Translations of the Writings of the Fathers down to A. D. 325," 24 volumes.

From the Ministry of Agriculture, Industry, and Commerce, Rome, 10 volumes and three pamphlets published by the department.

From the Central Bureau of Statistics, Stockholm, "Bidrug till sveriges officiela Statistik," 22 parts.

From the Medico-Chirurgical Society of Modena, 27 medical pamphlets.

From the Norwegian Government, "Norges Officiela Statistik," 1873, 13 parts, 4to; and 4 volumes on Norwegian Statistics.

From the State library of Virginia, 9 volumes of State documents.

In addition to the books which have been received, we are indebted to Major-General J. H. Lefroy, governor of Bermuda, a special friend of the Institution, for a series of manuscripts procured by him during a late visit to England, and presented through him by his relative, Mrs. Dundas, of Canon Hall, Larbert, N. B.

The following is a report on these manuscripts by Mr. Spofford, Librarian of Congress:

"These original records form a collection of the highest interest and value as materials of personal and political history at a period which must ever remain the most important era in the annals of the United States. One of the volumes contains twelve reports submitted to the lords of Her Majesty's treasury, by John Wilmot, Colonel Dundas, and the other commissioners, upon the losses and services of the claimants who were loyal to the British crown during the revolutionary war, and who were afterward indemnified by act of Parliament. Six reports in addition, signed by Colonel Dundas and Mr. J. Pemberton, commissioners, and extending from A. D. 1784 to 1789, are also embraced. Thirty-four of the manuscript volumes contain a large amount and variety of facts and testimony regarding the landed possessions and personal property of hundreds of British subjects in the New England States, as well as in New York, New Jersey, Pennsylvania, etc. As most of these papers have never been published, they are the more valuable and original and unique repositories of information regarding the persons to whom they relate, the descendants of many of whom still survive among the people of the United States."

The edition of the volume of the catalogue of Transactions of Learned Societies, originally prepared by the Institution, containing a list of the works of this branch of bibliography, deposited in the Library of Congress, having been exhausted, Mr. Spofford is about to publish a new edition containing all the late additions which have been made to the collection. It will also contain, in an appendix, a catalogue of scientific periodicals, with the date of publication of each volume, compiled under the auspices of the Smithsonian Institution, by Dr. H. Carrington Bolton, of the Columbia College School of Mines, New York.

TELEGRAPHIC ANNOUNCEMENT OF ASTRONOMICAL DISCOVERIES.

The important arrangement which was concluded between the Smithsonian Institution and the Atlantic cable companies in 1873, by which free telegraphic transmission of astronomical discoveries was granted between Europe and America, has been continued during the past year. The number of announcements, however, has not been as great as during the previous year.

The following list comprises the *asteroids* discovered in 1874:

No.	Name.	Discoverer.	Date.
135	Hertha	C. H. F. Peters, at Clinton, N. Y	February 18, 1874.
136	Austria	M. Palisa, at Pola	March 18, 1874.
137	Meliboea	M. Palisa, at Pola	April 21, 1874.
138	Tolosa	M. Perrotin, at Toulouse	May 19, 1874.
139		J. C. Watson	Oct. 10, 1874.
140	Siwa	M. Palisa, at Pola	Oct. 13, 1874.

Eight *comets* have been detected during the past year.

No.	Discoverer.	Date.
1	Winnecke, at Strasburg	February 20, 1874.
2	Winnecke, at Strasburg	April 11, 1874.
3	Coggia, at Marseilles	April 17, 1874.
4	Borelly, at Marseilles	July 25, 1874.
5	Coggia, at Marseilles	August 19, 1874.
6	Borelly, at Marseilles	December 6, 1874.

These comets, except No. 3, were strictly telescopic.

The number of amateur astronomers in the United States who are provided with telescopes of sufficient power to detect minute heavenly bodies is every year increasing, and the discovery of new comets and asteroids offers an interesting field for their cultivation. The plan adopted by Professor Watson, of Ann Arbor, furnishes a definite means for the discovery of asteroids. It consists in studying with great minuteness a narrow band in the heavens, of two or three degrees in width, extending at right angles to the ecliptic, twenty degrees or more on each side. At some time in the revolution of an asteroid around the sun it must pass through this band, and, if each fixed star in this circumscribed space be accurately mapped and its relative place be made familiar to the observer, any new object which presents itself within this area may be readily detected.

NATIONAL MUSEUM.

For many years after the Institution took charge of the National Museum only $4,000 was allowed by Congress for the annual expense on account of this duty. In 1871 the appropriation for this purpose was increased to $10,000, and in 1872 to $15,000, and for the last year to $20,000; the last-mentioned sum being sufficient for the present to defray the annual expense without encroachment on the income of the Smithson fund, nothing being charged on account of rent of the building. In addition to this, $10,000 was appropriated for the completion of the cases in the large room of the second story, devoted to ethnology. This money was expended in procuring cases in the form of tables with glass tops and sides for the exhibition of smaller articles.

The following report from Professor BAIRD gives an account of the additions to the museum and the various operations connected with it during the past year:

Increase of the National Museum.

As in previous years, nearly every region in North America, and a considerable number of localities in Central and South America, as well as in other parts of the world, have been represented in the collections of 1874; the following summary showing, in a general way, the more important of the acquisitions from a *geographical* point of view:

From *Greenland* has been received a collection of articles of Esquimaux dress and other interesting curiosities, including the skeleton of a polar bear.

The *arctic main land* of North America is represented by perfect skins, with the skeletons complete, of adult male and female musk-oxen, forming an acquisition that any museum would consider of great importance.

Alaska has been richly represented during the year by a good series of ethnological material of the Thlinket tribes of Sitka and the adjoining region, including a number of the stone implements which are now entirely gone out of use and very rare; also, from the Maglemut Esquimaux of the island of Nunivak, Behring Sea, a remarkably full series of their utensils, weapons, and carvings. This addition, with what had previously been obtained, gives to the National Museum a finer collection of Western Esquimaux material than exists in all other ethnological museums combined.

A series of dredgings has also been received, made in the Northern Ocean, in the vicinity of Kotzebue Sound, and in other portions of Behring Sea; a large collection of birds with their eggs, among them specimens of the *Sterna aleutica* and other rare species, and series of skins and skeletons of the fur-seals, &c.

Queen Charlotte's Island and Washington Territory.—From these we have received ethnological objects, consisting principally of elaborate carvings made by the Haidah Indians, a race excelling any other aboriginal people on the continent in the skill and variety of the designs which they engrave on bone and wood.

Oregon is represented very satisfactorily by a series of prehistoric remains obtained from shell-heaps. These are of extreme beauty of finish, and constitute a highly-prized addition to the ethnological collections of the Institution.

California, as usual, occupies a prominent place in the record of additions to the museum, more particularly in the line of archæology, including prehistoric remains from the shell-heaps, some of them opening a new page in American archæology in the variety and complexity of the objects, and in their great beauty of finish. The applications and uses of many of them constitute puzzling problems in ethnology.

From the Pacific coast we have also received specimens of the cetaceans, and an interesting and valuable collection of eggs.

Arizona, *Utah*, and *Colorado* are richly illustrated by the specimens collected by the various Government exploring expeditions, in all the departments of natural history and ethnology. These regions may almost be considered as more fully represented in the National Museum than any other portion of the continent, with the exception of Alaska. A collection of eggs from Arizona challenges competition for beauty of preparation and variety of species; also ethnological objects of much interest.

From *Montana*, specimens of the grayling fishes have been received, among which a new species has been described by Mr. Milner, *Thymallus montaniensis;* a collection of birds, and a fine specimen of mule-deer.

New Mexico is represented principally by specimens of Navajo workmanship, fossil remains, and minerals in much variety.

Dakota.—As in previous years, large collections, especially in natural history, have been received from this Territory, particularly from the officers of the Northern Boundary Survey.

Central portion of the United States.—The collections from this region have consisted principally of crania, stone implements, pottery, worked bones, &c., from Tennessee, Indiana, Illinois, Ohio, Iowa; minerals and rocks from Tennessee; skins of salmonidæ of Lake Superior; specimens of the Michigan grayling, and of the giant snapping-turtle from Louisiana.

Eastern portion of the United States.—We have received specimens of bone implements and other ethnologica from New York, Pennsylvania, and Virginia; fresh-water and land shells and Otsego bass from New York; young California salmon from the Susquehanna River; fossil ferns and a specimen of the Arkansas fly-catcher from Maryland; and fishes from Virginia.

Florida is well represented by human crania, shell-heap remains, and other ethnological objects, living alligators, fishes, shells, and reptiles;

among the latter a specimen of *Elaps distans*, a serpent previously unknown excepting in Arizona.

From *Newfoundland* we have had a series of stuffed skins of several species of seals of different ages.

From *Mexico* a collection of reptiles and fishes.

From *Cuba* a continuation of the complete series of species of fish, which the Institution has received from its correspondents on that island.

Central America, as usual, has furnished very important collections, among them birds and reptiles from the isthmus of Tehuantepec; specimens of the musical instruments of the aborigines of Guatemala; poisonous serpents of Nicaragua, and, above all, a series of mammals, birds, reptiles, fishes, shells, insects, and ethnology from Costa Rica.

South America.—The receipts from this part of the western hemisphere have not been very large, consisting principally of some casts of stone implements from ancient mines in Chili, and ethnological objects, birds, mammals, and serpents from Brazil, as well as a specimen of sea-lion from Patagonia.

Europe.—The additions of the year consist of marine shells, cretaceous fossils from Sweden, and skeleton of the white porpoise from Norway; also models of the common form of weir used in Denmark for the capture of fishes; minerals from Saxony; highly valuable specimens of crania and pottery belonging to the Anglo-Saxon period of British history; prehistoric objects from the celebrated locality of Solutré, among them numerous bones of the horse, the remains of which, to the number of many thousands of individuals, have been accumulated in a single depository.

Other parts of the world.—Among the most noteworthy of the collections received are those of fishes, crustaceans, seeds, bulbs, shells, &c., from the island of *Mauritius;* models of dwellings, articles of dress, specimens of fishes, crustaceans, corals, &c., &c., from the *Samoan Islands;* and fishes from *Kamtschatka*.

Not the least interesting and important of the collections of the year are "squeezes" from Egyptian antiquities, and a perfect copy of the Tanis or Canopus stone, from the museum at Boulak, of which a much inferior copy was already in possession of the Institution.

Miscellaneous.—The Navy of the United States has very largely contributed specimens collected during the voyages of the Portsmouth among the Pacific Islands; of the Narragansett in the Gulf of California and vicinity, embracing shells, fishes, birds, and ethnology; and of the Tuscarora in the Pacific Ocean, between the United States and the Sandwich Islands and Japan, consisting of the soundings taken while selecting a suitable line for a trans-Pacific telegraphic cable.

Systematic summary.—Having described the principal additions to the National Museum in 1874 in geographical order, it may not be amiss to refer briefly to them again in their systematic sequence, as likely to give a better idea of the actual increase in the scientific value of the collections.

Of the various additions received during the year, those which are most varied and comprehensive in their nature, and of most importance, have been derived from the labors of Mr. W. H. Dall and Mr. H. W. Elliott, in Alaska; of Mr. Archibald Campbell, Major Twining, and Dr. E. Coues, of the Northern Boundary Survey, in Dakota; of Major Powell, Lieutenant Wheeler, and Dr. Hayden, in Utah, Arizona, and Colorado; of the United States steamers Portsmouth and Narragansett, in the Pacific Ocean; of Capt. Nicholas Pike, in the Mauritius; of the United States Fish-Commission on the eastern coast of the United States; and of Professor Gabb, in Costa Rica.

Ethnology.—The Smithsonian Institution has been, for several years past, especially interested in extending the ethnological collections of the National Museum, desirous that this should embrace as full an illustration of American archæology as possible. The results of its efforts in this direction have been very satisfactory, few days elapsing without the receipt of one or more packages of specimens. These collections are so numerous, indeed, as to render it impossible to mention them all here; and we can only specify a few, referring to the list of donations for a statement in full.

By far the most important of these collections were those received from Alaska and the west coast of America and from Costa Rica, already referred to in general terms. The specimens procured by Mr. Dall furnish a full representation of the prehistoric antiquities of the islands and the main land of Alaska, as also of many of the objects at present in use among the Esquimaux, the Aleutians, &c. Mr. Elliott's collections relate more especially to Saint Lawrence Island, Behring Sea, a region previously unrepresented in any collection.

The collections made in Oregon by Mr. A. W. Chase and Mr. Paul Schumacher relate to the shell-heap deposits, and are quite unique in their character. Still more so are the gatherings made by Mr. Dall and Mr. Schumacher from the islands and main land of Southern California. The carvings by the Haidah Indians, collected by Mr. J. G. Swan, are of great interest and beauty.

The collections of Doctor Gabb, of both modern and prehistoric ethnology in Costa Rica, are of very great extent and of extreme value, and are supplemented by a collection of aboriginal musical instruments from Guatemala, furnished by Mr. Henry Hague.

Large numbers of stone implements, pipes, pottery, &c., have been received from the expeditions of Major Powell, Doctor Hayden, and Lieutenant Wheeler, from Governor Arny, of New Mexico, and from many localities in the interior and in the east, all together forming an aggregate of very great extent. Conspicuous among these are specimens of bone implements obtained by Mr. Frank H. Cutting in Central New York. Mr. J. H. Jenkins, of Northumberland, Pa., has increased the extent of his deposits by numerous additional objects. General M. C. Meigs, Quartermaster-General United States Army, has furnished ethnological specimens from Arizona of much interest.

Among the articles obtained from the Mississippi Valley is a remarkable stone pestle, or muller, from the Rev. Joshua Hailes, senior. This is stirrup-shaped, and quite unique in North America; although similarly-shaped objects, with the same function, are known in Central America and the Sandwich Islands.

A noteworthy article in this department consists of a specimen of ancient cloth from a rock-dwelling near Montezuma Wells, in Arizona, presented by Lieut. E. B. Hubbard. Dr. J. F. Snyder, of Illinois, has furnished a large number of disk-shaped, chipped stones, of great beauty.

Of Old World collections we have mentioned a copy of the Tanis or Canopus stone, presented by the Khedive of Egypt, and, through General Charles P. Stone, numerous "squeezes" of Egyptian antiquities, contributed by the latter gentleman; a series of Saxon crania, and other antiquities, from Professor Rolleston, of Oxford; specimens from the prehistoric burial-places near Solutré, presented by Professor Lartet, and valuable collections from the Samoan Islands, by A. B. Steinberger, esq.

Under the head of *Mammals*, an important acquisition is that of a perfect pair of skins and skeletons of musk-oxen, from Mr. Hardisty, of the Hudson's Bay service, in arctic North America.

Mr. P. T. Barnum, in pursuance of his liberal offer to place at the disposal of the Institution, for the use of the National Museum, all such animals from his menagerie as might die on his hands, has furnished specimens of the nylghau, the manatee, the dromedary, the sun-bear, and other species. A specimen of the sea-lion of Patagonia has been received from Doctor Burmeister, of Buenos Ayres. Henry W. Elliott has procured for us a series of skins and skeletons of the fur-seals. Doctor Gabb has furnished complete collections of nearly all the known mammals of Costa Rica, in great number. Professor Pagenstecker presented skins of various European mammals. A series of the seals of Newfoundland was received from Rev. M. Harvey; and Captain Scammon has contributed additions to the series of cetaceans of the Pacific Coast, especially that of California, it being his intention to render the collection of the National Museum as complete as he can make it. The objects received illustrate his important work on the marine mammals of the western coast of the United States.

The Vienna Museum has supplied skins and skeletons of several species of Old World mammalia. From Doctor Bessels has been received a skeleton of the polar bear, and from Doctor Yates casts of the teeth of the fossil elephant of California. Señor Albuquerque, of Brazil, has furnished living specimens of the coatimundi; and Doctor Nichols, of the Washington Insane Asylum, the body of a very large grizzly bear.

Specimens of the black-tailed deer and American panther were obtained for the Institution by Mr. James Stevenson, of Doctor Hayden's survey. One of the most important contributions of the year, as far as the mammalia of North America are concerned, consisted of several specimens of the black-footed ferret, (*Putorius nigripes*,) a weasel described by Mr. Audubon in 1843 from a single specimen, which has not been since caught until the present year, when specimens were transmitted to the Institution by Mr. La Munyon, Dr. Law, and Mr. L. H. Kerrick.

Especially noteworthy among the *birds* received during the year is a specimen of the dodo pigeon (*Didunculus strigirostris*) from the Samoan Islands, presented by Mr. A. B. Steinberger. This species is best known from having been collected by the Wilkes Exploring Expedition, and described nearly simultaneously by Sir William Jardine and Mr. Titian R. Peale. It is confined to these islands, where it is nearly extinct. This specimen is especially valuable from being presented entire in alcohol, thus furnishing an opportunity of a thorough anatomical investigation of its characteristics. A living specimen just received at the Zoological Garden in London has attracted great attention.

Mr. Lucien M. Turner, now stationed at Saint Michael's, in Norton Sound, as an observer in the Signal-Service, has sent a number of birds, with their eggs, of much interest, among them specimens of the *Sterna aleutica* and other rare species.

A cast of part of the skull of a remarkable fossil bird from the Sheppey clay, of England, (the *Odontopteryx toliapicus*,) has been received from Mr. Bryce M. Wright. Mr. Barnum has supplied, from the specimens that died in his menagerie, the cassowary, the emu, and the ostrich. From Dr. Gabb has been received a very large series of the birds of Costa Rica. Mr. J. E. Harting, of London, has supplied some rare specimens of the grallæ. Collections of the birds of Colorado have been furnished by Mr. C. G. Aiken and Mrs. Maxwell; of the Isthmus of Tehuantepec, by Professor Sumichrast; of the Prybilov Islands, from Mr. George R. Adams. Collections of the birds of Brazil were furnished by Señor Albuquerque, and of Buenos Ayres by Dr. Burmeister; a series of rare species from Ecuador was also received from the Wesleyan University, at Middletown, Conn.

A noteworthy fact is the receipt of a specimen of the Arkansas fly-catcher, killed in Maryland, and presented by Mr. Jouy, this species being usually confined to the western plains.

The most important of the collections of *eggs* received are those furnished by Captain Charles Bendire, United States Cavalry, from Southern Arizona; those from Dr. William A. Cooper, of Santa Cruz, California; from Florida by Professor Jenks, and from Alaska by Mr. Dall and Mr. Elliott.

The collections of *reptiles* received during the year have not been very extensive, the most important being the series furnished by Mr. Gabb from Costa Rica, and those brought in by the expedition of Lieutenant Wheeler. Captain Bendire has furnished a specimen of the rare *Heloderma horridum*, a curious lizard from Arizona; and several living alligators from Florida have been supplied by Messrs. Chandler and Boyd. Mr. John Potts, a correspondent of many years' standing, has again evinced his interest in the Institution by sending a collection of reptiles and fishes from Mexico. A living sea-turtle from Florida was presented by the honorable Secretary of the Navy, and a giant snapping-turtle of the Mississippi, by Mr. Boyd. Dr. Reuss has furnished collections of reptiles from Illinois, Professor Sumichrast others from the Isthmus of Tehuantepec, Mr. John Queseda the poisonous serpents of Nicaragua, and a series gathered during the operations of the Northern Boundary Survey was brought in by Dr. Coues. Mr. Meek obtained from Florida a specimen of *Elaps distans*, a serpent to which reference has already been made, as previously known only in Arizona.

The collections of *fishes* embrace some of the most noteworthy additions of the year, these having been made with special reference to the operations of Professor Baird as United States Commissioner of Fish and Fisheries. The most important of these were gathered by himself on the coast of New England, especially in the vicinity of Noank, Conn., where he had his headquarters during the past summer. These embrace full series of all the kinds known to occur in those waters, supplemented by rare specimens sent by his agents and correspondents at Wood's Hole, Portland, and elsewhere. Large numbers, too, of the fishes of the great lakes and of the Mississippi, &c., have been supplied, among them specimens of the grayling of Michigan and of Montana, including several new species; and series of white-fish from Maine, New Hampshire, and elsewhere, have also been received. Mr. E. G. Blackford, the well-known dealer in fish at Fulton Market, New York, has been especially serviceable in this connection by keeping a sharp watch over the rare and curious fish coming into New York, and sending them suitably packed in ice to Washington. By means of the various fresh fishes thus obtained, the series of casts of the food-fishes of the United States, commenced a few years ago, has been greatly extended during the past season, this now numbering over three hundred specimens, painted carefully from nature, and representing fishes and cetaceans, some of them of nearly a thousand pounds weight. This collection of casts is unique in this country, and is only represented on a smaller scale by that of Mr. Frank Buckland, in London, and that of the natural history museum of Trinity College, Dublin.

Other specimens of fishes are those from the coast of Virginia, supplied by Prof. H. E. Webster; skeletons of the fishes of South Carolina, from Mr. G. E. Manigault; specimens from the Sacramento Bay, sent by Mr. L. Stone; from the vicinity of New Bedford, by Mr. John H. Thomson; from Florida, by Mr. G. B. Goode; from the Susquehanna River, by Mr. T. H. Bean and Mr. Jas. Creveling; from Montana, by Dr. Hart; from Lake Superior, by J. T. Coleman; from Michigan, by D. H. Fitzhugh, jr., and Fred. Mather; from Cooperstown, N. Y., &c., by Captain Phinney,

Of fishes from regions outside of the United States, specimens have been furnished from the fresh waters of Central Europe, by Dr. Middleton Goldsmith; from the Pacific Ocean, by the United States steamer Portsmouth; from Kamtschatka, by Col. T. L. Lee; from Cuba, by Professor Poey and Professor Shepard; and from the Mauritius, by Capt. Nicholas Pike. The last-named collection is in great variety of species and admirable preservation, constituting one of the most important contributions ever made in this department to the National Museum. Professor Poey's collection is a continuation of a systematic series, which he has undertaken to supply, and which already embraces over a hundred species.

The Zoological Museum of Copenhagen has supplied models of the common form of weir used in Denmark for the capture of fishes.

The general collections of *marine invertebrates* have been from Mr. William H. Dall, from Capt. Nicholas Pike, and from the United States Fish Commission, among other series. In *mollusks* the collections of Captain Pike and Mr. Dall are especially rich.

A series of *shells* from the coast of Norway, by Mr. G. O. Sars, of Christiania, will be of much value for comparison with American forms. Numerous shells of fossil mollusks have also been received from various donors.

From the fact that the collections of *insects* have been transferred to the Agricultural Department, not much can be announced in the way of receipts in this department, all the specimens that have come to hand having been, as usual, delivered to that establishment. It may be worthy of mention, however, that the first collections made by the United States astronomical expedition for the observation of the transit of Venus, received at the Institution, consist of a series of butterflies from Brazil, furnished by Mr. Russell.

Of *plants* various packages have been received from the different Government expeditions, among them some interesting fossil species from Mr. Ambler and Dr. Stevens, of Virginia, and Mr. Sternberg, of Kansas. As heretofore, all the recent specimens have been transmitted to the Agricultural Department.

Among the more important contributions to the museum have been the specimens of *soundings* made by Commander Belknap, on the Tuscarora, during his labors in the Pacific Ocean. These are of very great extent, and promise to furnish large numbers of new species. They are now placed in the hands of Prof. Hamilton L. Smith for identification.

A series of dredgings has been received from the vicinity of Kotzebue Sound and other portions of Behring Sea, made by Captain Smith, of the Alaska Commercial Company.

Minerals in considerable number have been received, among them a series collected by Colonel Abert, of Tennessee, specimens deposited by Mr. J. H. Jenkins, of Northumberland, specimens from Berlandier as presented by General D. N. Couch, together with specimens from Saxony, given by Dr. Endlich; these are in addition to the large gatherings of the Government expeditions.

Dr. Endlich, in charge of the mineralogical department of the museum, states that, during the year 1874, 250 minerals have been placed in the cases, in addition to those mentioned in the last report, as well as 300 lithological specimens and 150 ores.

The metallurgical collection remains about the same.

The labeling of the minerals has been finished, and exhibits a type of what the method will be when the whole collection is completed.

A large number of minerals has been examined at the request of correspondents of the Institution, and their qualitative character determined. For purposes of education the Institution furnishes qualitative determinations of mineralogical specimens, but in no case does it undertake to furnish percentages of the different components of specimens, or give certificates, for commercial purposes, of their value.

The fossils are being arranged, and in the course of a year we hope to have series of duplicates for distribution.

During the past summer, Dr. Endlich was engaged in the southwestern portion of Colorado, in the San Juan mining region, in connection with the Hayden expedition, an account of which will be given in the reports of that establishment.

It is, of course, impossible to enumerate all the collections and specimens, or to give in these cursory notes anything more than a general idea of the nature of the receipts of the year. The complete list of donors, with the objects presented by them, will be found arranged alphabetically in the appendix to the report.

Work done in connection with the National Museum.

As might reasonably be supposed, the magnitude of the receipts during 1874 has required much time and labor to reduce them to order, exceeding as they did by far those of any previous year. The rapid rate of increase is evinced by a comparison with the data for 1873 and 1872, as follows:

The total number of entries for 1874 is 564, from 337 donors, and embraces 712 packages; for 1873 the numbers are 441, 241, and 680, respectively; and for 1872, 315, 203, and 544.

As regards the distribution of duplicate specimens to public establishments, &c., the records show 320 entries; these include donations of specimens to 40 foreign museums and zoologists and to 165 home institutions, and embrace 32 sets of mammals, 18 of birds and eggs, 4 of reptiles, (living and dead,) 4 of fishes, 3 of crania, 5 of insects, 63 of shells, 12 of plants, 2 of fossils, 106 of minerals, rocks, and building-stones, 7 of ethnological specimens, and 5 of diatomaceous earths; in all, 261 lots.

A table in the appendix shows the total number of specimens distributed, including also those deposited in the care of the Department of Agriculture and the Surgeon-General's Office.

Of specimens submitted to specialists for examination and report there have been 61 lots: Mammals to H. and J. A. Allen and to Dr. Sclater; birds to Geo. N. Lawrence; reptiles and fishes to E. D. Cope; insects to Messrs. Packard, Scudder, Edwards, Ostensacken, Uhler, Ulke, Stretch, Cresson, Thomas, Glover, Emerton, and Holden; shells to Messrs. Tryon, Binney, and Sandberger; crustaceans to S. J. Smith; marine invertebrates to A. E. Verrill; plants to Messrs. Gray, Rothrock, Vasey, Englemann, Olney, James, and Carson; microscopic material to Messrs. Smith and Seaman; mineral waters to Dr. Loew.

Six lots additional to the above have been lent for study.

The number of specimens sent out for investigation is approximately estimated as follows: Mammals, 2,000; birds, 900; reptiles, 100; fishes, 100; insects, 7,000; shells, 500; marine invertebrates, 400; ethnologica, 10; packages of microscopic material, 500; plants, 9,000; in round numbers about 20,000. Some of these are included among the specimens distributed.

It is no exaggeration to say that 40,000 specimens are represented by the 320 entries in the distribution-book.

Collecting apparatus has been lent to about fifteen expeditions and collectors, principally from the stores of the United States Fish Commissioner.

GOVERNMENT EXPLORATIONS AND SURVEYS.

The following is a brief sketch of the surveys made under the authority of the General Government during the year 1874, the specimens from which are to be finally deposited in the museum under the care of the Institution.

Explorations and surveys west of the 100th meridian, First Lieutenant George M. Wheeler, Corps of Engineers, in charge.

Nine separate parties took the field in 1874 for operations in portions of Nebraska, Utah, Colorado, New Mexico, and Arizona. The point of departure was Pueblo, Colorado Territory, in the valley of the Arkansas. The whole area entered and occupied lies south of the latitude of the Spanish Peaks, except that included in special journeys necessary to complete the triangulation commenced in 1873. This important work was delegated to Lieut. Wm. L. Marshall, Corps of Engineers, who brought to this task, besides professional and executive abilities, the experience gathered in his former labors upon this work. The total area assigned was a little less than 35,000 square miles.

Out of the nine parties, six were moving field-parties, having special areas conjoining along latitudinal and other lines, and connecting at certain triangulation and topographical stations.

A special party, under Doctor J. T. Rothrock, U. S. A., organized with a view to institute further investigations into the natural history of certain areas left unfinished in 1871, 1872, and 1873, in New Mexico and Arizona, departed from Santa Fé early in the season, and returned laden with rich and valuable collections of the flora and fauna of that great region; having carried on, in connection with their examinations, observations for altitudes of special points within the drainage area visited, throwing further light upon the geographical distribution of animal and vegetable life.

Two main distinct astronomical parties were occupied in establishing the co-ordinates of points immediately adjacent to the field of survey and others along the line of the Union Pacific Railroad, and were successful in accomplishing all that was laid out for them.

The results in the astronomical branches are, the conclusions of the observations necessary to determine the co-ordinates, and the astronomical meridian at the stations Las Vegas and Cimarron, N. Mex., the latitude of Pueblo, Col., the latitude and longitude of Sidney Barracks, Julesburgh, and North Platte Station in Nebraska, on the Union Pacific Railroad.

At the field astronomical stations sextant observations were carried on by the following officers in charge of the several parties: First Lieut. Wm L. Marshall, First Lieut. P. M. Price, Corps of Engineers; Second Lieut. C. W. Whipple, Third United States Artillery; First Lieut. R. Birnie, jr., and First Lieut. S. E. Blunt, Thirteenth United States Infantry. These stations have been numerous, answering all the requirements made upon them for checking special positions by a method in place of which nothing else could be made available.

The geodetic work included the establishment of 79 main triangulation stations, extending a net-work over the entire mountain-area occupied. Base-lines were measured at Trinidad and Pueblo, Colorado; Cimarron, Las Vegas, and Santa Fé, New Nexico. These bases control the triangulation which connects the belts of 1873 in Colorado, New Mexico, and Arizona, as well as those north and south from the line of the Union Pacific and Central Pacific Railroads.

In meteorology, except at the astronomical stations at Cimarron and Las Vegas, N Mex., the observations were conducted solely with a view to the determination of altitudes at prominent physical points within the area surveyed.

Though no person was actually assigned as geologist, Doctor H. C. Yarrow, U. S. A., and Professor E. D. Cope investigated the geology and paleontology of the Territory of New Mexico. The results obtained were highly interesting. The cretaceous beds yielded many fine fossil shells and teeth of extinct fishes, and the carboniferous limestone was found to be equally rich in specimens. A unique collection of a large number of beautifully preserved invertebrate remains was procured from the same formation. These are the deposits of a lake of a comparatively modern age, which abound in the remains of skeletons of the animals that inhabited the surrounding land. Mastodons of species quite different from those frequently found in the Eastern States were in abundance, while camels and horses had evidently existed in droves. One of the most singular discoveries was that of a deer which did not shed its horns; and the fossil remains further indicate that at this time several species of wild dogs existed to keep in check the herbivorous animals, while a large vulture, allied to the turkey-buzzard, was prepared to act as scavenger as occasion offered. In another locality crocodiles and turtles were very numerous. Among the large remains were those of the genus Bathmodon, which closely resembles the elephant in the feet and legs, but the tapir and the bear in the character of the skull. They were armed with formidable tusks, and their crania were very thick, as if designed to repel attacks.

In the line of archæology and ethnology were found the remains of ancient human dwellings which stand in lines on the summits of rocky crests, and on the more inaccessible and remote points of hills, with precipices of several hundred feet in depth on one or more sides; from these and burial places most interesting specimens of pottery, besides crania and skeletons, were obtained.

The mineralogical specimens collected have been carefully analyzed by Doctor Oscar Loew in the laboratory of the Smithsonian Institution.

Dr. H. C. Yarrow, in charge of the natural-history branch, with his assistants, have added more largely than ever before to our knowledge of the living fauna of large interior areas. Their results are soon to be worked up by themselves and other specialists, and the specimens afterwards deposited in the National Museum at the Smithsonian Institution.

As usual, a photographer accompanied the expedition, who this year was successful in obtaining special photographs of ancient ruins, of various Indian tribes, &c.

While the parties operated in the field, the office-force remained engaged in working up the results for publication.

The publications during the past year of the surveys under the War Department have been: the Progress Report of 1872, a preliminary catalogue of plants gathered in 1871, 1872, and 1873, and a preliminary report upon the ornithological specimens collected in the same years; the first in quarto, the two latter in octavo. An advance edition of the Topographical Atlas and other physical sheets was also published.

The total working-force taking the field without escorts, for the first time, was 86, including officers, assistants, and employés. The utmost harmony existed among all the parties, which largely conduced to correspondingly enhanced results. In regard to these surveys under the War Department, the following paragraph appears in the Annual Report of the Chief of Engineers to Congress: "By experience and improvements in methods and instruments, the value of the results is annually enhanced, and the cost of the work amply repaid."

It cannot fail to be gratifying to all who are interested in this class of investigations to be convinced that the proper basis for further systematic endeavor has been reached.

Survey under Professor Hayden.

This survey during the season of 1874 continued the work of 1873 westward of the 107th meridian of longitude in Colorado Territory. The entire area explored lies on the west slope of the main range of the Rocky Mountains, forming the eastern part of the drainage of the great Colorado River. The topographical and geological work included a carefully-surveyed area of about eighteen thousand square miles, much of it comprising some of the most rugged and mountainous scenery on the continent. The southern portion includes an area of nearly three thousand square miles, the greater part of which is at an elevation of 12,000 feet and upward. The first division of the party, under Mr. A. R. Marvin, operating in Northwestern Colorado, established 86 stations; the second division, under Mr. Gannett, which explored the rugged area between the Gunnison and Grand Rivers, also established 86 stations; while the third division, surveying the remarkably high country in the southwest, determined 65 stations, most of them being on peaks ranging from 13,000 feet and upward, the highest being 14,500 feet.

A fourth division, under Mr. G. R. Bechler, performed the important duty of measuring the roads, trails, passes, and carefully working up the contiguous topography, besides meandering a distance of about nine hundred miles. Mr. Bechler established 36 important stations, thus rendering more accurate and complete the general work of the survey.

A fifth party, under Mr. W. H. Jackson, the photographer, passed over the greater portion of Western Colorado, obtaining about four hundred negatives of the most characteristic scenery. These views have proved of great value in the topographical and geological studies; but the most interesting result was a series of views of the wonderful ruins in the cañons of the Mancos and Montezuma Rivers. The party found here remains of a rude civilization in the form of buildings, made of hewn stone laid in mortar. Among the ruins were various kinds of stone implements and glazed pottery, on some of which were figures of the sun. On the plains and mesas these ruins occupy considerable areas, indicating the former existence of a numerous population. In the cañons the stone dwellings are built high up in the caverns or crevices in the sides, from 800 to 1,000 feet above the bottom, in almost inaccessible positions. From all the information that could be obtained from the present race of Indians, these dwellings were inhabited at least eight centuries ago by a race of sun-worshippers, which were driven southward, step by step, by a persistent foe from the north.

The sixth division, under Mr. J. T. Gardner, continued the primary triangulation over the mountainous region of the southwest, extending into Utah, and connecting with some of Professor Powell's stations.

The seventh division was under the immediate direction of Professor Hayden, and made special studies of those portions of Colorado that presented rather complicated problems in geology. A careful survey was made of the Elk Mountains, of the Morainal deposits in the valley of the Upper Arkansas, and the coal-beds along the east base of the Colorado range of mountains from Cañon City to Cheyenne. The season's labors were in every respect successful, and a large amount of topographical, geological, and natural-history material was secured for the eighth annual report to the Secretary of the Interior.

The publications of the survey during 1874 were the Bulletin No. 1 and No. 2, and second series, Nos. 1, 2, 3; miscellaneous publications, Nos. 3, 4, 5, 6; Cretaceous Flora, by Leo Lesquereux, 7th Annual Report, (Colorado.)

Survey under Professor Powell.

This was the continuation of the geological and geographical exploration of the basin of the Colorado of the West in Utah, prosecuted for several years previous. For this work two parties were organized, one under the charge of Prof. A. H. Thompson, and the other under the immediate direction of Professor Powell himself. Each party had a number of assistants, and to the latter was added a photographer. The first party was employed in carrying forward the work in Central Utah, and the second party in Northeastern Utah.

The valley of the Sevier, near the town of Gunnison, was selected as the proper position for the base-line from which a series of triangles could be extended to the north, east, and south, and connected with those which had been established in former years.

For hypsometric determinations Green River City on the Union Pacific Railroad, Salt Lake City, Gunnison, and Pangwitch were selected, from their connection with railway surveys, as known points of reference for altitudes to be ascertained by the barometer.

The geographical determination of latitude and longitude rests primarily on the base-line, the terminations of which were established by astronomical observations. For latitude the zenith-telescope was employed, and for longitude telegraphic methods were adopted.

The material was collected for mapping and exhibiting the resources of a section of country heretofore but little known, embracing many ranges of mountains and plateaus, with valleys drained by streams which in places pass through deep and almost inaccessible gorges. Over the entire region surveyed the data were collected for determining the amount and distribution of lands which can be redeemed from sterility by irrigation, and also that of grass and timber lands. The coal-formations, which had been discovered in previous surveys in adjoining regions, were traced through the areas of the present survey, and many new beds discovered. It was found that the coal of Southern and Central Utah is distributed through a series of geological formations embracing most of the Tertiary and Cretaceous ages. The supply of coal of this region is, therefore, abundant, and much of it is said to be of good quality and widely distributed. The position of many of the more important mineral-lodes was determined, especially such as have been worked to a sufficient extent to enable the owners to acquire permanent titles from the Government, and these will be represented on the general map.

The geological structure of the region is exceedingly complex. A series of formations, embracing Tertiary, Mesozoic, Paleozoic, and Metamorphic rocks, are plicated on a grand scale, and displaced by faults of immense extent. During geological ages, and continued down to later periods, this region must have been the scene of great volcanic activity. Extensive fields of eruptive matter and large numbers of volcanic cones are exhibited. In many places there exist great escarpments, forming cañon-walls and lines of cliffs, exhibiting with great perfection the superposition and structure of rocks, from which interesting geological deductions can be made.

The great system of monoclinal folds and faults discovered in former years, crossing the grand cañon of the Colorado, was found to be extended into the region of this year's survey. The lithological geology was studied so far as the opportunities permitted, and large collections of rocks made, especially of the volcanic formations widely distributed in geological succession. From the sedimentary rocks fossils were obtained abundantly sufficient to indicate the ancient flora and fauna of the region. The Territory is traversed by profound gorges, which conduct off the small amount of rain-fall not evaporated. Although the amount of water carried by the streams is small, the great elevation of the country above the sea gives it the velocity of a torrent, and being mingled with stones, its erosive action exhibits effects unequalled, perhaps, in any other part of the globe. On the mountains and plateaus of this region, wherever an altitude of 9,000 feet, or more, is reached, evidences of ancient glacial action are found.

Interesting ethnological results were obtained. Two important tribes of Indians were again visited, the Ŭ-in-tats and Seuv-a-rits, usually known as the Uinta Utes and She-be-riches, and much additional knowledge of the words and grammatical construction of their language was secured, as also a series of facts relating to the naming of tribes and confederacies, with fresh information as to their political organization. It so happened that while the surveyors were among these Indians, messengers arrived from the Go-si-Utes, of Western Utah and Eastern Nevada, bringing information of great rains and of the gradual rising of the Great Salt Lake, indicating, as they supposed, a great calamity, and calling upon the tribes we have mentioned to join them in religious ceremonies to appease the anger of the waters, lest in their rage and coming power they should destroy all the land and the people who lived thereon. The state of religious excitement which ensued enabled Professor Powell to increase his knowledge of their mythology and religion, in directions which previous to that time had been closed to him. On these subjects the Indians are usually reticent. Believing in sorcery and that a knowledge of their religion and organization can be used by their enemies to their disadvantage, they forbear to give any information on these subjects. But under the excitement above mentioned their reserve was neglected, and facts revealed which had previously been only partially understood. Previous to this no definite information had been obtained as to their religious worship, or whether they had any system of appeasing the displeasure of their gods.

A large number of articles to illustrate the various arts among these people, in addition to those made in previous years, was collected, so that the specimens in the National Museum for the study of the civilization of these tribes are more extensive, perhaps, than for any other on the American continent. Attention was also given to the ancient remains in the valley of the Colorado, and interesting additions have been made to the facts already known. A number of additional ruins were discovered, and observations made for depicting on a map scores of ancient towns or hamlets. Copies of picture-writings and stone implements of various kinds were obtained. The ethnological investigation embraces language, mythology, folk-lore, and the means of obtaining subsistence.

A large number of photographs was taken, which served to assist the draughtsman in delineating the topographical features of the country; also another series of the Indians themselves, intended to illustrate their dress, habits, and other characteristics.

Survey under Hon. Archibald Campbell.

This survey was for the continuation of the boundary-line along the forty-ninth parallel of latitude, between the United States and the British possessions. The distance remaining to be surveyed during 1874 was three hundred and fifty-eight miles, from longitude 106° 12′ to longitude 114° 05′. It was divided into two parties, the astronomical and the topographical.

During the season of 1874 the work was executed in the same manner as before, under the agreement made between the chief astronomers of the United States and British commissions, to the effect that the officers of the United States were to determine astronomical stations at intervals of forty miles, and to survey a belt of territory five miles wide south of the parallel, the English to determine a similar series of astronomical stations, and to survey an equal belt of topography north of the line.

The astronomical party, in charge of Maj. W. J. Twining, was organized in Saint Paul, Minnesota, on the 1st of June, and reached the point of operation on the 1st of July. The shortness of the season, and the great distance to be traveled after the work should be completed, required that it should be finished early in September. The party was, therefore, pushed to the utmost limit of endurance, and by the 1st of September the eight astronomical stations assigned to the United States had been determined, and the line had been connected with the last previous station of the boundary at the summit of the Rocky Mountains. In four months, this expedition accomplished a journey of 3,700 miles, besides surveying and marking 358 miles of the boundary-line.

The topographical party remained in the field both winter and summer from the 1st of June, 1873, until the present time, with the exception of two months in the spring of 1874. They have demonstrated that instrumental work can be done in that high latitude, even in the most rigorous part of the winter, where the country is wooded; but on the open plains the exposure is dangerous. That portion crossed by the line surveyed during 1874 was found to be an open plain, entirely destitute of timber, but easily practicable for wagon-trains, except in the vicinity of Frenchman's Creek and the crossing of Milk River, where wide detours had to be made to avoid the bad-lands. From longitude 106° to the crossing of Milk River the country is unattractive, the rain-fall is small, and water consequently scarce during the summer. The soil is alkaline, and produces mostly sage-brush and cactus. From the Sweet-Grass Hills to the Rocky Mountains its character is entirely changed. The rain-fall appears to be ample. The belt along the foot of the mountains, in addition to scenery of rare beauty, presents to the eye of the practical man the more solid advantage of an unsurpassed fertility. Northwestern Montana is still the range of immense herds of buffaloes, whose numbers, according to Major Twining, contrary to the commonly-received opinion, are constantly increasing. This region is the country of the Blackfoot and Piegan tribes of Indians. It is also the debatable ground of the North Assinaboines, the Gros Ventres of the prairie, and the River Crows, while an occasional war-party of the Sioux may be found as far northwest as the Sweet-Grass Hills. With the exception of the Sioux, these tribes appear to be peaceably enough disposed.

Collections and observations in natural history were made at almost every point along the boundary-line by Dr. Elliott Coues, surgeon and naturalist of the expedition, although it is to be regretted that he was not supported by an adequate corps of assistants, particularly in the departments of geology and botany. Large collections were made and sent to the Institution, an account of which is given in the report of Professor Baird. It is to be hoped that ample time may be allowed Dr. Coues for the preparation of his final report, in order that the results of his field-work may be fully elaborated in illustration of the flora and fauna of a portion of the United States of which comparatively little is known.

MISCELLANEOUS.

The Institution, as in former years, has been in harmonious co-operation with the Department of Agriculture, the Army Medical Museum, and the Corcoran Art Gallery. With the first it has deposited plants and other articles relating to agriculture; to the Medical Museum it has transferred a large number of articles pertaining to comparative anatomy and materia medica, and has received in return ethnological specimens; in the third, the Corcoran Art Gallery, it has deposited a number of paintings, articles of statuary, engravings, &c. A list of these several deposits will be found in the appendix.

It may be mentioned that the present Secretary of the Institution has been chosen one of the trustees of the Corcoran Art Gallery, and thus the connexion between these two establishments has become more intimate. The Gallery has been opened during the past year under very favorable auspices, and bids fair to be an important means of improving the intellectual and moral condition of the citizens of Washington, as well as a perpetual monument of the beneficent liberality of its founder. Since its first opening to the public on the 19th January, 1874, it has been visited by 75,000 persons. It has an endowment of $900,000, and had an income last year of upward of $62,000.

Fog-Signals.—During the last summer I devoted a considerable portion of my vacation to investigations in regard to sound in its application to fog-signals, the results of which have been published in an appendix to the Light-House Report for 1874.

These investigations, which were a continuation of those of former years, tend to establish the fact that sound is susceptible of a kind of refraction, due to the unequal velocity of the upper and lower current of the air, by which the sound-ray is in some cases bent upward, and consequently passes far above the head of the distant auditor, and in others is refracted downward to the surface of the earth, and is thus perceived at a much greater distance. This principle explains the peculiar action of the wind on sound, as well as various abnormal phenomena which have been observed from time to time in the operation of fog-signals; also the discharge of cannon during battles, of which the sound was heard at remote points, though inaudible at those much nearer the explosion.

Fish inquiry and propagation.—It may be remembered that an act of Congress was passed in February, 1871, directing an inquiry to be made into the causes of the decrease of the food-fishes of the United States, to be prosecuted by a commissioner appointed by the President, from the civilian employés of the Government, and to serve without salary. Professor Baird, of this Institution, received this appointment and entered upon his duties.

In 1872 his sphere of labor was extended by instructions for the employment of such measures as might increase the food-fishes of the country; and reports from time to time have been made of the results of the work.

The growing interest in this subject, and the belief that the objects to be accomplished were of great importance to the country; have induced larger and larger appropriations from Congress, and the sphere of the labors of the commissioner has been extended accordingly. His work is prosecuted under two distinct heads: first, that of an inquiry into the causes of the decrease of food-fishes; secondly, that of their multiplication.

In prosecuting the inquiry referred to he has established himself at points on the sea-coast where the fisheries it was desirable to investigate are carried on, and, by inquiries on his own part and those of his assistants, he satisfied himself as to the condition of the fisheries, and the extent to which they have been diminished, and the steps to be taken for their restoration.

He has embraced the opportunity thus offered, to carry on a thorough survey of the natural history and physics of the ocean, thus doing for the coast portion of the territory of the United States what the explorations of Professor Hayden, Lieutenant Wheeler, and Major Powell are accomplishing for the Territories of the West.

His operations during the summer of 1874 were carried on at Noank, Conn., his field of investigation extending from Narragansett Bay on the east, to the mouth of the Connecticut River on the west, and to the eastern end of Long Island on the south.

As usual his presence, with the facilities at his command, attracted a large number of visitors, among them some of the most eminent naturalists of the country, who were thus enabled to carry on important researches in natural history, all of them having a more or less direct bearing upon the objects of the commission. Professor Verrill, of Yale College, has been associated with Professor Baird from the beginning of this branch of investigation, and as usual labored indefatigably during the season.

The results of the labors of 1871 at Wood's Hole have already been published in a volume which constitutes a work of standard excellence. The report for 1872 is nearly ready for publication, and that for 1873 is well advanced. The second division of his duties, that of the work of propagation of food-fishes, was directed more especially to the multiplication of the shad and salmon. Owing to the late period at which the appropriation for this purpose was available, the operations in regard to the hatching of shad were not commenced until June, when camps were successively established on the Delaware, the Hudson, and the Connecticut; that on the Hudson in connection with the fish commissioners of New York, and that on the Connecticut with the commissioners of that State.

Owing to the death of Dr. Slack, who was in charge of the station on the Delaware, very little was done on that river. On the Hudson a very considerable number of shad was obtained and distributed, apart from those introduced into the river by the State commissioners themselves. The greatest amount of the work, however, was done at South Hadley Falls, on the Connecticut River. The fish here being very abundant, many young fish were hatched and distributed, mainly under the direction of Mr. James W. Milner, to various localities in many States, extending as far west as Minnesota, south to Texas, and east to Maine, the total number thus supplied amounting to over two millions.

The operations in regard to salmon were still more satisfactory, being carried on at two establishments; one on the McCloud River, in California, under the charge of Mr. Livingston Stone, and the other on the Penobscot River, in Maine, under Mr. Charles G. Atkins. The former furnished six millions of eggs, of which one million were hatched and placed in the Sacramento River, the others being transported to hatching-houses in the East, and the young subsequently placed in the waters of the New England and Middle States, in addition to those of Maryland, Virginia, West Virginia, North Carolina, Louisiana, Texas, Ohio, Indiana, Illinois, Wisconsin, Minnesota, and Iowa.

The establishment at Bucksport, on the Penobscot, has also yielded over three million eggs. These have not yet been distributed, as they are not sufficiently far advanced, but they will be planted principally in the waters of the New England, Middle, and more northern of the Western States.

The importance of these measures for the artificial propagation of fish may be readily understood from the fact that the actual results from one pair of shad or salmon, treated artificially, fully equal those from one hundred, and, according to some, one thousand pairs, when left to perform this function naturally.

Deep-sea soundings.—Professor Baird has made a series of observations on temperatures of the sea-water at different depths, the results of which will be published in his report as United States Fish Commissioner.

The Institution has received, for investigation, from the Bureau of Navigation, Navy Department, under Commodore Ammen, a large number of specimens of deep-sea soundings, collected in the Pacific Ocean by the officers of the United States steamship Tuscarora, Commander G. E. Belknap. These specimens have been referred for microscopic examination to Prof. Hamilton L. Smith, of Hobart College, Geneva, N. Y., who has undertaken the investigation, and will report the result as soon as the work is finished.

Polaris Artic Exploration.

During the past year Dr. Emil Bessels has been engaged at the Smithsonian Institution in working up that part of the scientific material which was saved from the collections of the voyage of the Polaris in the years 1871–'73. The results of the investigations will be given in three volumes, of which the first is nearly ready to be put in the hands of the printer. This volume contains—

Part I. Hydrography and meteorological observations at sea.

a. Hydrographical remarks relating to Baffin's Bay, Smith's Sound, and Robeson Channel.

b. Temperature of the sea and its specific gravity at different depths.

c. Ice of Smith's Sound and its motion.

d. Tidal observations made at Polaris Bay, comprising eight lunations.

Part II. Meteorology.

a. Temperature both at Polaris Bay and Polaris House, the second winter quarters.

b. Effect of the direct heating power of the sun

c. Effect of terrestrial radiation.

d. Hygrometrical observations.

e. Atmospheric pressure.

f. Winds.

g. Face of the sky.

h. Ozone.

i. Rain and snow.

Part III. Psychrometrical tables, giving the relative humidity, force of vapor, and dew-point for each tenth of a degree from 32° to —45°.

Part IV. Astronomical observations.

Part V. Magnetism and aurora.

Part VI. Pendulum experiments.

The second volume will be devoted to natural history, comprising zoology, botany, geology, palæontology, mineralogy, &c.

The third volume will comprise the ethnology of the Esquimaux.

The whole will be copiously illustrated by wood-cuts and charts, and published under the auspices of the Navy Department.*

Chemical Laboratory.—During the past two years the laboratory of the Institution has been in charge of Dr. Oscar Loew, the chemist and mineralogist of the Wheeler survey, and during this time he has made various analyses for the Institution of minerals, mineral waters, and other substances referred to the Institution for examination by the Government and other parties.

In behalf of the Wheeler expedition he has investigated and analyzed the waters of thirty-four mineral springs of New Mexico and Colorado, many soils of the arable lands of Arizona and New Mexico, rocks such as basalts, rhyolites, trachytes from New Mexico, coals of various localities in Colorado and New Mexico, lake and river deposits, minerals, such as turquois, garnets, zeolites, plants used for medicinal purposes by Mexicans, &c., &c.

Photography.—The photographic laboratory, under the direction of Mr. T. W. Smillie, has been in continued operation during the past year; a series of photographs having been made of ethnological and natural history specimens for the use of the Institution, and a large amount of work done for others, especially for the Government surveys. The establishment of a photographic laboratory has been of great convenience to the Institution, and has been attended with but little expense. It affords at once the facility of photographing specimens and copying charts and other illustrations, while the support of the artist has been furnished by work performed for other parties.

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* For the expense of the illustrations, Congress appropriated $15,000 in March, 1875.

Light-House duty.—I have been a member of the Light-House Board since its first organization, and during all this time have discharged the duties of chairman of the committee on experiments. On the resignation of Admiral Shubrick I was elected chairman of the board. I was honored with this election not entirely on account of the services I had rendered in the way of scientific investigations, but principally because I belonged neither to the Army nor the Navy, of which it was desirable that neither should claim predominance. The duty, however, pertaining to this office has been much more arduous than I anticipated. Indeed, in order that I might attend to it without interfering too much with my devotion to the affairs of the Institution, it was necessary that the board should be recalled to a previous usage, namely, that of meeting every week and transacting the principal business through its committees, instead of meeting quarterly and intrusting the operations of the establishment almost entirely to the two secretaries and the chairman, under which plan the latter was obliged to be in continual attendance at the Light-House office.

I am gratified to be able to state that, although some dissensions have occurred on account of the want of definite assignment by the original law of Congress of the relative duties of the Army and Navy while on light-house service, yet that the whole system at present is in an efficient state of activity.

It may be proper to remark that, for the labor which I have bestowed upon the light-house service for upward of twenty years, I have received no other remuneration than that which results from the conscious feeling of having successfully labored in some degree to advance the efficiency of a service which involves the protection of life and property, and is one of the benevolent institutions tending to facilitate the relations of distant countries with our own.

CONCLUSION.

From the foregoing statement it will be evident that the Institution is successfully prosecuting the plan adopted for realizing the benevolent intention of its founder in the way of increasing and diffusing knowledge among men; that its funds are again in a prosperous condition, and that its reputation and usefulness are still on the increase.

Respectfully submitted.

JOSEPH HENRY,
Secretary Smithsonian Institution.

WASHINGTON, *January*, 1875.

APPENDIX TO THE REPORT OF THE SECRETARY.

Table showing the number of entries in the record-books of the United States National Museum at the close of the years 1873 *and* 1874, *respectively.*

Class.	1873.	1874.
Mammals	11,625	12,294
Birds	65,950	68,361
Reptiles and amphibians	8,222	8,293
Fishes	12,514	13,808
Skeletons and skulls	13,290	14,408
Eggs	16,710	17,062
Crustaceans	2,194	2,204
Annelids	100	100
Mollusks	24,756	24,757
Radiates	3,139	3,142
Invertebrate fossils	7,725	7,727
Minerals	8,108	9,178
Ethnological specimens	13,084	16,415
Total	187,417	197,749

Increase for 1874, 10,332.

Approximate table of the distribution of duplicate specimens to the end of 1874.

Class.	Distribution to the end of 1873.		Distribution during 1874.		Total to the end of 1874.	
	Species.	Specimens.	Species.	Specimens.	Species.	Specimens.
Skeletons and skulls	389	1,114	40	116	429	1,230
Mammals	1,038	2,990	1,091	1,789	2,129	4,779
Birds	24,580	37,885	299	322	24,879	38,207
Reptiles	1,975	3,220	16	42	1,991	3,262
Fishes	2,717	5,748	54	67	2,771	5,815
Nests and eggs of birds	6,676	16,770	496	1,100	7,172	17,870
Insects	2,748	6,294	900	2,000	3,648	8,294
Crustaceans	1,078	2,650	....	....	1,078	2,650
Shells	84,637	187,292	5,152	8,000	89,789	195,292
Radiates	583	778	....	....	583	778
Other marine invertebrates	1,844	5,160	....	....	1,844	5,160
Plants and packages of seeds	23,370	39,705	5,000	10,000	28,370	49,705
Fossils	4,112	10,141	13	13	4,125	10,154
Minerals and rocks	5,453	11,152	3,414	5,100	8,867	16,252
Ethnological specimens	1,886	1,969	64	100	1,950	2,069
Diatomaceous earths, (pkgs)	83	812	175	200	258	1,012
Total	163,169	333,680	16,724	28,849	179,883	362,529

ADDITIONS TO THE COLLECTIONS OF THE SMITHSONIAN INSTITUTION (UNITED STATES NATIONAL MUSEUM) IN 1874.

Abert, J. T. One box of geological specimens from Nashville, Tenn.

Aiken, C. E. A collection of birds from Colorado; a mounted specimen of little striped skunk, (*Mephitis bicolor*,) and two bottles containing contents of the scent-bags of *Mephitis americanus* and *Mephitis bicolor*.

Albuquerque, Señor Don Frederico. Skins of humming-birds, fungi, &c.; two living specimens of coati-mundi, (*Nasua*, sp.,) from Brazil.

Alden, Mr. One barrel of skulls, from an Indian mound near New Smyrna, Fla.

Ambler R. C. One box of fossil plants from Virginia.

American Sardine Company, New York. Specimen boxes of American sardines.

Anderson, Thomas C. One package of minerals from Ellison Station, Ky.

Anderson, William. Two boxes of stone implements and shells from Indian grave, from Perry Co., Ohio.

Andrews, Dr. Robert R. Nine microscopic slides.

Arny, General W. F. M. Seeds of stone-pine and cigarita-shucks from the Navajo Indians, New Mexico.

Ashton, L. H. One specimen of fossil fish from Green River Station, Wyo.

Atkins, C. G. See under *Washington, U. S. Commission of Fish and Fisheries.*

Avery, T. C. One skin of duck-hawk, (*Falco anatum*,) from Greensborough, Ala.

Bagster, C. B. Specimens of spiders, (prepared.)

Baird, Prof. Spencer F. One specimen of marmoset monkey, (*Hapale jacchus*,) in the flesh; a collection of earthen vases, (28 pieces,) from Peru; a collection of fur garments, miscellaneous ethnologica, and minerals, from Greenland; a collection of plants, from the collection of the late Major Rich. See, also, under *Washington, U. S. Commission of Fish and Fisheries.*

Baker, Capt. John. A collection of shells from Florida.

Banks, T. C., jr. One specimen of salamander, (*Notophthalmus viridescens*,) from Wallingford, Conn.

Barcena, Mariano. See under *Mexico, Sociedad de la Historia Natural.*

Barfoot, Joseph L. See under *Salt Lake City, Salt Lake Museum.*

Barnum, Phineas T. Specimens, in the flesh, of cassowary, (*Casuarius indicus*,) nylghau, (*Portax tragocamelus*,) dromedary, (*Camelus dromedarius*,) sun-bear, (*Helarctos tibetanus*,) and skeletons of emu and ostrich.

Battle, Thomas H. Specimens of abnormal hens' eggs from Raleigh, N. C.

Batty, J. H. Two boxes of bird-skins; mounted specimen of great horned owl, (*Bubo virginianus ;*) one box of bird-sterna.

Bean, Tarleton H. A collection of fresh-water fishes from Bainbridge, Pa.; a collection of stone implements from Wyoming, Luzerne, Bradford, and Lancaster Counties, Pa. See, also, under *Washington, U. S. Commission of Fish and Fisheries.*

Beardslee, Com'r L. A., U. S. N. Specimens of young of *Dorosoma cepedianum* from the Potomac River, of *Salmo fontinalis* and *Etheostoma*, sp., from Little Falls, N. Y.; tusk of walrus (*Rosmarus obesus*) from the North Pacific Ocean.

Beatts, James W. Specimens of agates and opals from Lake Superior, Texas, and Germany.

Beck, Hon. James B. Specimens of minerals from Kentucky.

Beckett, George. A collection of minerals from the vicinity of Williamstown, Vt.

Beckwith, Capt. N. W. A skeleton of "devil-fish," (*Lophius americanus*,) from the Bay of Fundy; one Chinese stink-pot.

Belknap, Com'r G. E., U. S. N. See under *Washington, Navy Department, Bureau of Navigation.*

Bendire, Capt. Charles, U. S. Cavalry. Two boxes of birds' eggs from Arizona; two bottles of Coleoptera from vicinity of Tucson, Ariz.; a specimen of *Heloderma horridum* in alcohol.

Bergen, Norway; Bergen Museum. Specimen of dolphin, (*Delphinus leucopleurus*,) from the coast of Norway.

Bessels, Dr. Emil. See under *Washington, U. S. Navy Department, Polaris Expedition.*

Billopp, John S. One specimen of black wood-pecker, (*Hylotomus pileatus*,) in the flesh.

Binney, W. G. Two specimens of *Carinifex Newberryi.*

Blackford, E. G. Fresh specimens of fishes: blue-backed trout, (*Salmo oquassa ;*) striped bass, (*Roccus lineatus ;*) tautog, (*Tautoga onitis ;*) cod, (*Morrhua americana ;*) salmon, (*Salmo salar ;*) white perch, (*Morone americana ;*) saury pike, (*Scomberesox scutellatus ;*) Spanish mackerel, (*Cybium maculatum ;*) leather-jacket, (*Oligoplites occidentalis ;*) drum, (*Pogonias chromis ;*) red snapper, (*Lutjanus aya ;*) sturgeon, (*Acipenser brevirostris*,) &c., &c.

Boardman, George A. Caudal vertebræ of porcupine (*Erethizon dorsatus*) from Milltown, Me.

Boteler, Alexander R. One Indian stone implement from near Front Royal, Warren Co., Va.

Bowers, Mr. Specimens of muscovite from Ackworth, N. H.

Boyd, C. H. One specimen of alligator terrapin, (*Gypochelys temminckii*) from New Orleans, La.

Bradford, A. A living specimen of red fox (*Vulpes fulvus*) from Washington, D. C.

Breese, W. L. One skin of crested cormorant, (*Graculus dilophus.*)

Brewer, James D. See under *Washington, U. S. Commission of Fish and Fisheries.*

Brinsmade, C. E. One bottle of coleoptera from Fort Sully, Dak.

British Museum. See under *London.*

Brown, M. R., U. S. Revenue Marine. One specimen of Dana's coral (*Astrangia Danæ*) from Lewes Beach, Pa.

Brown University. See under *Providence.*

Bruhin, Thos. A. Specimens of supposed new species of *Vaccinium.*

Bruner, C. C. One specimen of hair-worm (*Gordius aquaticus*) from Oktibbeha, Miss.

Brush, Prof. G. J. A collection of minerals.

Bryan, O. N. One specimen of fossil *Arca* from Prince George Co., Md.

Buell, Sarah A. A specimen of asbestus from Maryland.

Buenos Ayres; Museo Publico de B. A., Prof. H. Burmeister. A collection of bird-skins from South America; skull and skin of seal (*Otaria leonina*) from Patagonia.

Buie, D. M. Indian skull and ethnological specimens from Wilmington, N. C., (on deposit.)

Burmeister, Prof. H. See under *Buenos Ayres.*

Byers, William N. One specimen of muscovite from Colorado.

Canfield, K. One specimen of selenite from Kansas.

Carpenter, Capt. W. L. Specimens of reptiles' and birds' eggs from Omaha, Nebr. See, also, under *Washington, Department of State, Northern Boundary Survey.*

Carroll, Michael. Prepared specimens of the gullets and skin of unborn cub of the harp-seal from Bonavista, Newfoundland.

Charleston, S. C.; Mus. of the Med. Col., Dr. G. E. Manigault. Mounted skeletons of sheepshead, (*Stenotomus argyrops*,) and drum, (*Pogonias chromis*;) fossils from the phosphate-beds of South Carolina.

Chandler, L. H. A living alligator, (*Alligator mississipiensis*,) young, from Florida.

Chase, A. W. Ethnological specimens from shell-heaps in Oregon; drawings by a "medicine-man" of the Ta-ta-tin tribe, Crescent City, Oreg.

Cheever, D. A. A bottle of orthoptera from Colorado.

Chicago, Academy of Natural Sciences; Dr. J. W. Velie. Two mounted skins of birds.

Christiania, Norway; Zoological Museum; Prof. G. O. Sars. A collection of shells from Norway.

Clarke, Prof. F. W. Specimens of cyprinodonts from Massachusetts.

Clarke, N. W. See under *Washington, U. S. Commission of Fish and Fisheries.*

Clitz, Gen. H. B., U. S. A. A shoulder-blade of buffalo, with Indian paintings.

Cock, George. One specimen of aquacreptite from Chester Co., Pa.

Cockerill, J. H. Two minerals.

Coffin, Charles C. Specimens of iron-ore, with fossil ferns, from Muirkirk, Prince George Co., Md.

Coleman, J. T. Four salmon-skins from Ishpenning, Mich.

Collins, W. H. A mounted specimen of king-eider duck (*Somateria spectabilis*) from Detroit, Mich.

Commagére, Frank Y. Ethnological specimens and tooth of narwhal (*Monodon monoceros*) from Greenland.

Cooper, George P. Specimens of insects.

Cooper, W. A. A collection of birds' eggs and nests from Santa Cruz, Cal.

Copenhagen; Museum of Zoology. A model of Danish fish-weir.

Cornwall, Prof. H. B. See under *Princeton, Museum of the College of New Jersey.*

Couch, Gen. D. N. The Berlandier Collection of minerals from Mexico, eleven boxes.

Coues, Dr. Elliott, U. S. A. See under *Washington, Department of State, Northern Boundary Survey.*

Coulon, Dr. Louis. Specimens of ancient pottery from Central Europe; a collection of alcoholic mammals.

Cowen, Gen. B. R., Assistant Secretary of the Interior. An Indian pipe of peace smoked at the great council of the Grand River agency by the Umpapa Sioux.

Creveling, J. P. Specimens of California salmon (*Salmo quinnat*) one year old from the Susquehanna River.

Cushing, Frank H. A collection of bone implements from an Indian grave near Medina, N. Y.

Dall, William H., Coast Survey, U. S. A. Thirty-seven boxes and kegs of general zoological and ethnological collections from Alaska and California.

Davenport, Iowa; Davenport Academy of Natural Sciences. A collection of Indian crania from mounds in Iowa.

Davidson, Mr. Specimens of magnetite and of ornamental woods from Salem, Oreg.

Davis, D. W. Specimen of a root encircling a water-pipe, from Washington, D. C.

Derer, J. T. Specimens of minerals from Georgia.

Dickinson, E. Thirteen eggs of the marbled godwit, (*Limosa fedoa.*)

Dickie, J. A. Specimen of mineral from Independence, Va.

Douglas, Harry. Two steel-tipped Indian arrows from Kansas.

Douglas, James, jr. Plaster-casts of stone hammers from Campaña Serena, Coquimbo, Chili.

Dow, Capt. J. M. A living specimen of burrowing owl (*Spheotyto cunicularia*, var. *floridanus*) from the Gulf Stream, 200 miles from the coast of Georgia; a collection of fishes from Panama; two packages of Central American minerals.

Dowell, B. F. Specimens of fossil wood from Oregon.

Dury, Charles. Nests of worm-eating warbler (*Helminthophaga vermivorus*) and Carolina wren, (*Thryothorus ludovicianus.*)

Dutton, Thomas H. Specimens of quartz arrow-heads from Uniontown, D. C.

Edmunds, Colonel. Specimens of bowlder rocks from White Top Mountain, Grayson Co., Va.

Edwards, Vinal N. See under *Washington, U. S. Commission of Fish and Fisheries.*

Elliott, Henry W., Special Agent Treasury Department U. S. Eight boxes of general zoological and ethnological collections from the North Pacific; skins of sea-otter, (*Enhydra marina,*) and skulls of Walrus, (*Rosmarus obesus,*) from Alaska; one tank of alcoholic specimens from the Aleutian Islands; augite crystals from Saint George Island, Alaska.

Endlich, Dr. Frederic M. A collection of minerals from Saxony. See also under *Washington, Interior Department, U. S. Geological Survey.*

Farrell, Norman. A skull of large turtle from the Oclocknee River, Florida.

Fay, Joseph S. A specimen of oyster (*Ostræa virginiana*) from Wood's Hole, Mass.

Ferguson, Maj. T. B., Maryland Commissioner of Fisheries. Two living specimens of black bass, (*Micropterus salmoides.*)

Field, S. T. Specimen of fish (*Gila*, sp.) and fossil fish from Green River, Wyoming.

Finck, Hugo. An alcoholic specimen of frog (*Rhinostomus dorsalis*) from a lagoon near Cordova, Mexico.

Fish, W. S. Asbestos paper and cloth from Scotland.

Fisher, Davenport. A collection of minerals from Ackworth, N. H.

Fitzhugh, D. F. Specimens of fishes from Bay City, Mich.

Fletcher, W. W. Specimens of white-fish (*Coregonus*, sp.) from New Hampshire.

Fly, Major. Specimens of silver-ores from Chihuahua.

Forsyth, W. A. Manganese-ores from West Virginia.

Fossick, T. L. & Co. Specimen of polished marble from Ingleton, Ala.

Fraine, Thomas W. Mounted specimens of birds from Rochester, N. Y.

Gabb, Prof. William M. Two stone idols from Santo Domingo; eight boxes of general zoological and ethnological collections from the Talamanca expedition, Costa Rica.

Gass, A. M. Specimens of vegetable gum and galls from Campo, San Diego Co., Cal.

Gidney, Love and Burton, (through *U. S. Department of Agriculture.*) Specimens of minerals from Cleveland Co., N. C.

Golden, H. W., through *C. G. Atkins.* Specimens of *Osmerus*, sp., from Belgrade, Me.

Goldsmith, Dr. Middleton, Vermont Commissioner of Fisheries. Collections of fishes and crustaceans from Central Germany and from the river Seine.

Goode, G. Brown. Specimens of menhaden (*Brevoortia menhaden*) and parasites (*Cymothoa prægustator*) from the Potomac River; a collection of fishes from the lower Saint John's River, Florida. See, also, under *Middletown; Museum of Wesleyan University;* and *Washington, U. S. Commission of Fish and Fisheries.*

Gordon, Hon. John B. One specimen of coal from Alabama.

Griggs, Hon. A. S. Specimens of minerals from Washington Territory.

Griswold, C. D. See under *Washington, U. S. Commission of Fish and Fisheries.*

Hague, Henry. Aboriginal musical instruments from Guatemala.

Hailes, J. Bones and pottery from an Indian mound in Tennessee.

Hardenburgh, L. R., U. S. Surveyor-General for California. Specimens of borax from California; minerals from California.

Hardestie, W. L., Hudson Bay Company. Skins and skeletons of male and female musk-oxen (*Ovibos moschatus*) from the Barren Grounds of Arctic America.

Harmer, Miss Helen A. An Indian pipe from Keshena, Wis.

Harris, D. W. Specimen of stag-horn beetle from Louisiana.

Hart, Dr. Charles A., U. S. A. Specimens of Montana grayling, (*Thymallus montanensis*, n. sp. Milner.)

Hart, James M. Specimens of brown coal from Oswego, N. Y.

Harting, Dr. J. E. Skins of grallae from various localities.

Harvey, F. S. Four specimens of oölite from Des Moines, Iowa; specimens of roots (*Psoralea esculenta*) used as food by the Indians, from vicinity of Humboldt, Iowa.

Harvey Rev. M. Arm of squid (*Architeuthis monachus*) from Newfoundland; series of mounted skins of Newfoundland seals.

Haskins, Anderson. One malformed hen's-egg from Washington, D. C.

Hayden, Dr. F. V. See under *Washington, Interior Department.*

Hayes, Dr. W. W. Two stone implements from San Luis Obispo, Cal.

Haynes, Benjamin. Minerals from Bergen Hill, N. J.

Heidelberg University Museum, Professor Pagenstecher. Skins of mammals from Europe; skeleton, fossil, of *Halitherium Schinzi.*

Hemphill, Henry. A collection of insects, marine invertebrates, &c., from San Diego, Cal.

Henshaw, H. W. See under *Washington, War Department; Surveys west of the one hundredth meridian.*

Hereford, Dr. Thomas P. An aboriginal stone pipe from Coalburg, W. Va.

Herron, J. P. A specimen of muscovite from Atlanta, Ga.

Hessel, Dr. Rudolph. Specimens of the cocoons of the common leech (*Hirudo medicinalis*) from Germany.

Hill, George W. Indian stone implements from Ashland, Ohio.

Hill, J. B. A living specimen of alligator, (*Alligator mississippiensis*,) young, from Florida.

Hitchcock, G. N. A skin of bullock's oriole (*Icterus Bullocki*) from San Diego, Cal.; eggs of unknown bird.

Holst, Christian, Secretary of the Royal University of Norway. Specimens of chalk fossils from Gotland Island, South Sweden.

Hoope & Coit, Port Monmouth Fishery, New York. Sample boxes of shadines (*Brevoorta menhaden*) in oil.

Homer, Charles F. Indian stone implements, &c., from Phœnix, Ariz.

Hubbard, Lieut. E. B., U. S. Artillery. Specimens of cloth from Montezuma Wells, Ariz.

Hutchins, W. D. Specimens of minerals from Lexington, Ind.

Hyer, J. D. Specimens of darter (*Pileoma caprodes*) from the Potomac River.

Jackson, E. E. One living specimen of soft-shell turtle (*Platypeltis ferox*) from the Congaree River, South Carolina.

Jennings, S. K. Fossil shark's teeth and sea-urchin spines from Rienzi, Miss.

Jenkins, J. H. Specimens of azurite from Arizona; agates from Lake Superior, (on deposit;) a collection of Indian stone implements from Central Pennsylvania, (on deposit.)

Jenks, Prof. J. W. P. See under *Providence, Museum of Brown University.*

Jenkins, Admiral Thornton N., U. S. N. Specimens of bricks from the great wall of China.

Jones, John P. A slab with Indian carvings from Keytesville, Mo.

Jones, Dr. William H., U. S. N. See under *Washington, Navy Department.*

Jordan, Dr. Franklin. A specimen of *Voluta junona* and mineral from Jacksonville, Fla.

Jouy, P. Louis. Skin of Arkansas fly-catcher (*Tyrannus verticalis*) from Maryland.

Kapena, Governor. One wooden pipe from the Sandwich Islands.

Kellogg, Dr. A., through *U. S. Coast Survey Office.* A collection of mosses and lichens from Alaska.

Keenan, J. R. Mississippi State currency, one one-dollar bill.

Kelly, D. M. Specimens of clay from Little Wolf, Minn.

Kenny, William H. A living snake (*Boa*, sp.) from Brazil.

Kercheval, A. W. One specimen of specular hematite from West Virginia.

Kerrick, L. H. One skin of black-footed weasel (*Putorius nigripes*) from Western Kansas.

Ketcham, Dr. Ovaries and stomach of black bass (*Micropterus salmoides*) taken in the Potomac River.

Kinney, Thomas W. A cast of an Indian carving from Ohio.

Krider, John. Specimens of shot.

La Munyon, J. W. One skin of black-footed weasel (*Putorius nigripes*) from North Platte, Kansas; head of grebe; shells from the Loup River, Missouri.

Lamb, *George.* Specimens of coral from Florida.

Latham, *James H.* A collection of fishes from Florida.

Latham, *Capt. Silas B.* A collection of shells from Florida.

Law, *Annie E.* One box of ethnological specimens from Dalton, Ga.; ethnological specimens from a mound, Chilhowee Valley, Little Tennessee River.

Law, *Dr.* One skin of black-footed weasel (*Putorius nigripes*) from Cache La Poudre Valley, N. Colo.

Lea Isaac. One specimen of *Lioplax cyclostomiformis;* two specimens of *Carinifex Newberryi.*

Ledyard, *L. W.* One specimen of harlequin snake (*Elaps fulvius*) and insects from Orange Bluff, and one pipe-fish (*Syngnathus*, sp.) from Saint Augustine, Fla.

Lee, *Col. Francis L.* Fishes from Kamtchatka.

Lenthall, *John.* Bas-relief of human head, funeral urn, and lachrymal urn, from Baii, Italy.

Lewis, *Dr. James.* A collection of land and fresh-water shells from New York; a collection of univalve shells from various localities.

Lincecum, *Dr. Gideon.* A cranium of negro outlaw from Long Point, Tex.; insects from Texas.

Loew, *Dr. Oscar.* See under *Washington*, *War Department*, *Surveys west of the one hundredth meridian.*

London, *British Museum.* Cast of Assyrian tablet.

Lloyd, *H. H.* One star-fish and a fish's tail from Port Townsend, W. T.

Lartet, *Dr.* See under *Lyons*, *France; Musèe d'Histoire Naturelle de Lion.*

Lowry, *T. W.* One specimen fossil *Unio* from Elizabeth City Co., Va.

Luce, *M. M.* Ten specimens of white-fish (*Coregonus*, sp.) from Industry, Me.

Lynch, *Judge.* Indian pipe and tomahawk from Weldon, N. C., (on deposit.)

Lyons, *France; Musèe d'Histoire Naturelle de Lyon*, *Dr. Lartet.* A collection of fossil bones and flint implements from the prehistoric station at Solutré, near Macon, (Saone et Loire,) France.

McCook, *General A. McD.*, *U. S. A.* One bill of a saw-fish (*Pristis antiquorum*) from Santiago Harbor, Tex.; one Comanché lance, and scalp of white child, from Fort McKavit, Tex.

Mackenzie, *Dr. E. H. R.* A box of dried leaves.

McLaughlin, *W. B.* Specimens of young herring (*Clupea elongata*) from spawning-ground, southern head of Grand Manan, N. B.; one egg of raven (*Corvus carnivorus*) from Grand Manan.

McRitchie, *Capt.*, *U. S. N.* One Eskimo dog-trace from Greenland; specimens of cryolite from Ivigtot, Greenland.

Manigault, *Dr. G. E.* See under *Charleston*, *S. C.*, *Museum of the Medical College.*

Mapes, John S. Specimens of mineral (Titanite?) from Warwick, N. Y.

Marsh, H. J. A package of pebbles from New Jersey.

Mason, Judge Charles. Specimens of rocks from Mount Vesuvius.

Mason, Prof. O. T. One Comanche tomahawk-pipe from Fort Sill, Idaho; specimens of betel nuts from Rangon, Burmah.

Mather, Fred. Fins of grayling (*Thymallus tricolor*) from Honeoye Falls, N. Y.; one specimen, in the flesh, of the grison (*Galictis vittata;*) specimens of grayling from Honeoye Falls.

Maxwell, Mrs. M. A. Skins of gray-crowned finch (*Leucosticte tephrocotis*) from Boulder, Colo.; a collection of land-shells from Colorado.

Meek, Prof. F. B. One specimen of harlequin snake, (*Elaps distans*,) other reptiles, and insects, from Florida.

Meigs, General M. C. Specimens of Indian pottery from Arizona; Indian pipe from the Dog tribe; four pieces of pottery from Pueblos, Tex.; a fresh skin of wapiti, (*Cervus canadensis.*)

Middletown, Conn.; Museum of Wesleyan University, G. Brown Goode, curator. Skins of raptores from New England; skins of birds from Ecuador.

Mexico; Sociedad de la Historia Natural, Mariano Barcena. Specimens of opals from Mexico.

Miller, Dr. C. A. A collection of fossils from the Cincinnati group; a collection of stone implements from the banks of the Ohio River, between Meigs Co., Ohio, and Madison, Ind.

Mills, Clark. Casts of the heads of Eskimo Joe and Hannah.

Milner, James W. See under *Washington, U. S. Commission of Fish and Fisheries.*

Mitchell, Dr. S. Weir. Specimens of Indian pottery from Michigan and New Jersey.

Moffatt, Dr., U. S. A. Six Hoopa Indian arrows, (through U. S. Army Medical Museum.)

Montfort, Rev. J. G. Specimens of land-shells from United States.

Moody, Elisha. Sponges and Indian stone hatchet from Florida.

Moragné, Dr. N. H. Specimens of bones, shells, &c., from a mound near Pilatka, Fla.

Moore, L. P. Specimens of minerals from Winchester, Va.

Moore, N. B. Fossil bones, bird-skins, and eggs from Manatee, Fla.

Morrison, F. L. Specimens of silver-ores from Mexico.

Morrison, J. R. D. Specimens of minerals.

Müller, Prof. Rudolph. Specimens of fungi from Carthagena, Ohio; stone implements and bones from Carthagena, Ohio.

Murray, Com'r, U. S. N. Teeth of fossil shark, and bill of a saw-fish, (*Pristis antiquorum*,) from South Carolina.

Nash, Thomas H. One articulated human skeleton. (Purchased.)

New Albany, Ind.; Academy of Sciences. Casts of bone implements from shell-heaps, New Albany, Ind.

Nichols, Dr. C. H., Government Asylum for the Insane. Specimens, in the flesh, of grizzly bear, (*Ursus horribilis,*) and bald eagle, (*Haliaetus leucocephalus.*)

Nickerson, George Y. One bird's egg (*Megapodius,* sp.?) from the Celebes Islands.

Ocean Trout Co., Port Monmouth, N. J. Sample boxes of "ocean trout," (*Brevoortia menhaden,*) pickled.

Oldmixon, Dr. George S., U. S. A. Specimens of grayling (*Thymallus montanensis,* Milner, n. sp.,) from Montana.

Otis, Col. Harrison G. Petrological and botanical specimens from Guadaloupe Island, Lower Cal.

Oxford, England; Museum of Nat. History; Prof. George Rolleston. Four boxes of stone implements and pottery, and crania of ancient Saxons, from England.

Pagenstecher, Professor. See under *Heidelberg, University Museum.*

Palmer, Dr. Edward. Two packages of ethnological specimens from Florida.

Papineau, E. A. One box of pinned coleoptera from Topeka, Kans.

Parker, W. F. A tail of black-tailed deer (*Cervus macrotis*) from Red Cloud agency.

Peshall, Capt. Charles. One stone knife from Clark Co., Ark.; shells and quartz crystals from Ouachita Valley, Ark.

Phinney, Captain. Five specimens of Otsego white-fish (*Coregonus otsego*) from Otsego Lake, N. Y.

Pierson, William L., U. S. vice-consul. One specimen of meteoric iron from Casas Grandos, Chihuahua, Mex. See under *Washington, Department of State.*

Pike, Col. Nicholas, U. S. consul. Twelve packages of general zoological collections from Mauritius and the Indian Ocean.

Poey, Prof. Felipe, University of Havana. Collections of minerals, skins, and alcoholic specimens of fishes, from Cuba.

Pohlenz, Franz. Two iron-stone nodules from Washington, D. C.

Poor, C. R. One specimen sponge from Nantucket.

Potts, John. A collection of reptiles and fishes from Mexico.

Powell, Maj. J. W. See under *Washington, Interior Department.*

Pratt, W. H. Specimens of *Helix multilineatus* from Iowa.

Princeton, N. J.; Museum of Princeton College; Prof H. B. Cornwall. A collection of minerals from various localities.

Prentiss, Dr. C. A. A fresh skin of white pelican (*Pelecanus erythrorhynchus*) from Dade Co., Mo.

Providence, R. I.; Museum of Brown University; Prof. J. W. P. Jenks. Skins and eggs of birds, and Seminole leggings from Central Florida.

Putnam, Joseph Duncan. Skin of *Thomomys,* sp. from Camp Brown, Wyo.

Queredo, John, U. S. N. Specimens of venomous serpents from San Juan River, Nicaragua.

Reid, J. W. One specimen of fossil crinoid from Urbana, Ohio.

Reuss, Dr. A. Collection of serpents, fishes, and ethnological specimens from Belleville, Ill.

Rice, Jos. K. One mineral from Hackettstown, N. J.

Robeson, Hon. George M. One specimen of sea-turtle from Key West, Fla.

Roome, James H. One fish-skin.

Russell, Mr., U. S. N., (U. S. Steamer Swatara.) Specimens of *Lepidoptera* from Brazil and the Cape of Good Hope.

Salt Lake City; Salt Lake Museum; J. L. Barfoot. One bottle of crustacea (*Artemia*, sp.) from the Great Salt Lake.

Sandberger, Prof. Fridolin. Specimens of *Helices* from Germany.

Sanford, C. O. A living specimen of great horned owl, (*Bubo Virginianus*.

Sars, Prof. G. O. See under *Christiania, Norway; Zoological Museum.*

Scammon, Capt. C. M., U. S. Revenue Marine. Specimens of baleen from three species of whales; skull of *Orca;* skeleton of striped porpoise, (*Lagenorhynchus obliquidens;*) embryo of Baird's porpoise, (*Delphinus Bairdii;*) whale's skeleton, &c., &c.; all from the Pacific Ocean.

Schneider, A. P. Two specimens of common mole (*Scalops aquaticus*) from Falls Church, Va.

Schoolcraft, Mrs. H. R. A specimen of "soap-tree" wood from Chili; one flint arrow-head and specimen of Indian weaving from Arizona; specimen of Indian matting from Durango, Mexico.

Schumacher, Paul, U. S. Coast Survey. A collection of marine invertebrates from California; a collection of ethnological specimens from San Luis Obispo, Cal.

Seely, Commander H. B., U. S. N. One specimen of porcupine fish (*Paradiodon hystrix*) from Fort Jefferson, Fla.; skins of mammals from Europe.

Seyboth, Robert, U. S. Signal-Service, through *U. S. Signal Office.* Two bottles of insects from the summit of Pike's Peak.

Shaw, James. One box of fossils from Mount Carroll, Ill.

Shepard and Weston. Fresh specimen of namaycush (*Salmo nemaycush*) from Bay City, Mich.

Shepard, Prof. C. U. Two jars of fishes from Cuba.

Shepherd Bros. A box of pebbles from Warren Co., Iowa.

Silliman, Prof. Benjamin. Specimens of priceite, gold, and zircon, from California.

Sipa, George, and Sons. One specimen of peacock-coal from Allegheny Co., Pennsylvania.

Slack, Dr. J. H., New Jersey Commissioner of Fisheries. Specimens of young and embryonic California salmon (*Salmo quinnat*) from Troutdale hatching-house.

Slagle, John W. One box of stone implements from Congaree River, South Carolina.

Smith, J. Lawrence. Specimens of limestone-rock from Louisville, Ky.

Smith, R. K. Silver-ores from Arkansas.

Snyder, Dr. J. F. One box of leaf-shaped stone implements from Beardstown, Cass Co., Ill.

Stabill, Joseph, through Tarleton H. Bean. One tortoise-shell ear-ring from the Fejee Islands.

Stearns, R. E. C. Seeds of coniferous trees from California.

Steinberger, Col. A. B., Special Agent State Department U. S. Collections of ethnological and botanical specimens and marine invertebrates, *Didunculus*, sp., and other birds from the Samoan Islands.

Sternberg, Charles H. Specimens of ammonites from Ellsworth Co. Kansas; fossil plants from Fort Harker, Kans.

Stevens, R. P. Specimens of Devonian plants from Rockingham Co., Virginia; gold-ores from Venezuela; Indian mulling-stone from Venezuela.

Stevenson, Prof. J. J. Two stone chisels from West Virginia and Colorado.

Stevenson, James. One skin of mule-deer, (*Cervus macrotis;*) a specimen, in the flesh, of puma (*Felis concolor*) from Colorado.

Stilwell, E. M., Maine Commissioner of Fisheries. One specimen of cusk (*Lota maculosa*) from Moosehead Lake, Maine.

Stone, Gen. C. P. Casts and squeezes of Egyptian antiquities.

Stone, Livingston. A collection of alcoholic fishes from the Sacramento River, California; specimens of *Salmo*, sp., from Dublin Pond, Keene, N. H.

Stratton, L. Specimens of marine algæ from Cape Flattery, Washington Territory.

Streets, Dr. T. Hale, U. S. Steamer Portsmouth. See under *Washington, Navy Department.*

Stuart, William R. One Indian calumet from Augusta Co., Va., (through Hon. P. H. Hereford.)

Sumichrast, Prof. F. A collection of birds from Mexico.

Sutherland, John. One specimen of lump-fish (*Cyclopterus lumpus*) from New York Harbor; one specimen of *Zoarces anguillaris* from New York market.

Swan, James G. A collection of ethnological specimens, Indian stone implements, from Washington Territory.

Tegetmeier, W. B. Mounted specimens of poultry-skins and skulls from England.

Thompson, John A. Vegetable pleistocine remains from Jerseyville, Jersey Co., Ill.

Thomson, J. H. Specimens of fishes from New Bedford, Mass.

Thompson, J. K. Specimens of wood from Iowa.

Tisdale, E. J. One specimen of painted bunting (*Cyanospiza ciris*) from Mooreville, Ala.

Turner, Lucien M., U. S. Signal-Service. Collection of birds and eggs from Oonalashka and Saint Michael's, Alaska.

Van Fleet, Walter. One specimen of Blackburnian warbler (*Dendroica Blackburniæ*) and scarlet tanager (*Pyranga rubra*) from Watsontown, Pa.

Velie, Dr. J. W. See *Chicago Academy of Natural Sciences.*

Vienna, Austria; Zoological Museum; Dr. L. Reettenbacher. A collection of skins and skeletons of mammals and birds.

Wahl, Dr. W. H. One specimen of asbestos from Philadelphia, Pa.

Wallbaum, A. One specimen of crystalline limestone from Sagetown, Ill.

Walker, Com'r J. G., U. S. N. One lot of fossil shark's teeth from Charleston, S. C.

Wallace, J. One specimen of snowy owl (*Nyctea nivea*) from New York market.

Walton, W. F. Specimens of silver-ores from White Pine District, Nev.

Washington, D. C.:

Department of State, U. S. A., United States Survey of the Northern Boundary, (Hon. Archibald Campbell, Commissioner.) Zoological, botanical, and ethnological collections made by *Dr. Elliott Coues, naturalist of the expedition;* skeletons of elk, (*Cervus canadensis,*) and beaver, (*Castor canadensis,*) collected by *Capt. W. L. Carpenter, U. S. A.* See elsewhere, under the names of *Col. Nicolas Pike, Charles Weile,* and *William L. Pierson, U. S. Consuls,* and *Col. A. B. Steinberger, Special Agent.*

Treasury Department, U. S. A. See under the name of *H. W. Elliott.*

United States Revenue Marine. See elsewhere, under the names of *Capt. C. M. Scammon* and *M. R. Brown.*

United States Coast Survey. See under the names of *A. W. Chase, William H. Dall,* and *Paul Schumacher.*

War Department, U. S. A.:

United States Army. See under the names of *Gen. M. C. Meigs, Gen. H. B. Clitz, Gen. A. McD. McCook, Capt. Charles Bendire, Capt. W. L. Carpenter,* and *Lieut. G. M. Wheeler.*

Surgeon-General's Office, United States Army Medical Museum, (Dr. G. A. Otis in charge.) Ethnological specimens from Pembina, Dak.; one stone hammer; one Uté necklace of human toes; one skin bag. See, also, under the names of *Drs. Elliott Coues, Peter Moffatt, H. C. Yarrow, G. S. Oldmixon, Charles A. Hart,* and *J. T. Rothrock, medical officers United States Army.*

Surveys west of the one hundredth meridian, Lieut. G. M. Wheeler in charge. General zoological and botanical collections made by *Dr. H. C. Yarrow, Dr. J. T. Rothrock, Mr. H. W. Henshaw,* and *Dr. Oscar Loew.*

Signal-Service U. S. Army. See under the names of *Sergeants Robert Seyboth* and *Lucien M. Turner.*

Navy Department, U. S. A.:

U. S. Navy. See under the names of *Com'r J. G. Walker, Com'r*

Murray, *Com'r Skerritt*, *Com'r Seelye*, *Admiral Jenkins*, *Com'r L. A. Beardslee*, *Com'r George Dewey*, *Com'r G. E. Belknap*, *William Russell*, *Mr. Quevedo*.

Bureau of Navigation, *Commodore Daniel Ammen*. Specimens of dredgings from the coast of California, *United States Steamer Tuscarora*, *Commander G. E. Belknap*; zoological and botanical collections from the coast of Lower California, the Gulf of California, and the Reviligigedo Islands, *United States Steamer Narragansett*, *Commander George Dewey*, collected by *Surgeon William Evers;* zoological, botanical, and ethnological collections, from Palmyra and other Polynesian Islands, *United States Steamer Portsmouth*, *Commander J. S. Skerritt*, collected by *Surgeons William H. Jones*, and *T. Hale Streets;* nine specimens of bottom-soundings from the Gulf-coast of Mexico, *United States Steamer Fortune*.

Polaris Expedition, *Capt. C. F. Hall*. One skeleton of polar bear (*Ursus maritimus*) from Greenland, collected by *Dr. Emil Bessels*.

Interior Department, *U. S. A.:*

General Land-Office. See under the names of *Surveyors-General L. Hardenburgh* and *John Wasson*.

United States Geological Survey of the Territories, (*Prof. F. V. Hayden in charge.*) Four boxes of minerals from Colorado, collected by *Dr. F. M. Endlich*.

United States Commission of Fish and Fisheries, (*Prof. Spencer F. Baird*, *Commissioner.*) Sixty boxes general zoological collections from Noank, Conn., and vicinity, by *Prof.*, *A. E. Verrill*, *G. Brown Goode*, and *Tarleton H. Bean;* one barrel of zoological specimens from Holyoke, Mass., collected by *J. W. Milner* and *C. D. Griswold;* fishes from Waukegan, Ill., collected by *J. W. Milner;* three boxes of *Salmonidæ* from Sacramento River, Cal., collected by *Livingston Stone;* eggs of white-fish (*Coregonus albus*) from Michigan, collected by *N. W. Clark;* eggs of salmon (*Salmo salar*) from Bucksport, Me., collected by *C. G. Atkins;* fifteen boxes of zoological specimens from Wood's Hole, Mass., and Cape Cod, collected by *Vinal N. Edwards;* models of dory used on the coast of New England, and of drying-flakes, from Portland, Me.; one model of fish-way from *James D. Brewer*, Muncy, Pa.

Smithsonian Institution; Survey of the Colorado, (*Maj. J. W. Powell* in charge.) Four boxes of fossils from Colorado.

Department of Agriculture, (*Hon. Frederick Watts*, *Commissioner.*) One specimen of *Menopoma alleghaniensis;* one bottle of reptiles.

Wasson, *John*, *U. S. Surveyor-General for Arizona*. One package of minerals from New Mexico, and silver-ores from Santa Torreas mine; minerals from Keystone mine, Arizona.

Waterhouse, *Dr. A.* A collection of butterflies from Chautauqua Co., N. Y.

Webb, John S. One specimen of white weasel (***Putorius noveboracensis***) from Chuckatuck, Va.

Webster, Prof. H. E. A collection of fishes in alcohol from Eastern Shore of Virginia.

Weile, Charles, U. S. consul. One specimen of boa ("*Tigre*") in alcohol from Guayaquil.

Wesleyan University. See under *Middletown.*

Whitaker, James C. One Indian vase from Baldwin Co., Georgia.

Wilkinson, A. G. A collection of fishes from British provinces.

Williams, D. H., M. D. A collection of silver-ores from Northern Mexico.

Williams, Milo G. A collection of plants from Ohio.

Williamson, Thomas. Specimens of fossil ferns and lepidodendra from Tennessee.

Wilson, J. K. Collection of minerals, for examination, from Forest City, Mo.

Wing, Melvin. One stone implement from Mount Vernon, Ohio.

Wood, August H. One skull of the Virginia deer (*Cariacus virginianus*) from New York.

Wright, Bryce M. One cast of a bird's head (*Odontopteryx toliopica*) from the London clay, Sheppey, England.

Wright, D. T. A collection of crania and Indian relics from Clarksville, Tenn.

Yarrow, Dr. H. C. Specimen of cod (*Gadus morrhua*) from New York; seven bird-skins from the Alps, Switzerland; *Juniperus* from Arizona, and bird-trap from France. See also under *Washington, War Department, Surveys west of the one hundredth meridian.*

Yates, L. G. Casts of teeth of the fossil elephant (*Mastodon*) from Solano Co., Cal.

Yeager, F. M. A collection of minerals from Pennsylvania.

Zoological Society of Philadelphia. Fresh specimen of yak, (*Poëphagus grunniens.*)

LIST OF ARTICLES DEPOSITED BY THE SMITHSONIAN INSTITUTION IN THE CORCORAN ART-GALLERY, WASHINGTON.

1. Portrait of the late Hon. William C. Preston, of South Carolina, by G. P. A. Healy.

2. Portrait of the late Ex-President John Tyler, of Virginia, by G. P. A. Healy, 1859.

3. Full-length portrait of M. Guizot, of France, by G. P. A. Healy.

4. Cast of a bas-relief of "Phœbus," from a marble found in the ruins of ancient Troy, in 1873, by Dr. Schliemann, of Athens, Greece, who presented it to the Smithsonian Institution.

5. Marble head of Diana, (antique.)

ENGRAVINGS AND ETCHINGS.

1. Lioness and Young. Engraving, by J. F. Ridinger.
2. Two engravings of deer. Engraving, by J. F. Ridinger.
3. Silenus. Line engraving, by Bolsevert.
4. Hercules. Line engraving, by Rottsseler.
5. A Centaur instructing Achilles. Line engraving, by Bervic, after Regnault.
6. An Interior. Line engraving, by Vischer, after Ostade.
7. A Family Concert. Line engraving, by J. G. Wille, after G. Schalken.
8. Holy Family. Line engraving. (Artist unknown.)
9. Holy Family. Line engraving, by B. Desnoyers, after Raphael.
10. Aurora. Line engraving, by Raphael Morghen, after Guido.
11. An Old Beggar. Mezzotint, by Townley, after Dance.
12. Christ Healing the Sick. Etching. (Artist unknown.)
13. Cows. Etching, by Roos.
14. Horses, (two.) Etching, by Paul Potter.
15. Eleven etchings, by Rembrandt.
16. Fireside. Etchings, by Boissieu.
17. Goats, (two.) Etchings, by Berghen.
18. Eleven etchings, by Ostade and others.
19. Twelve etchings, by Clodowiecki.
20. The Nativity and Adoration of the Kings, by Henrich Goltzius.
21. Bruggemann Album of Photographs, illustrating the altar-screen in the cathedral at Schleswig.
22. Photograph of a Memorial Tablet, executed in wood, by P. Claurren, of Satrup, a plain farmer.

LIST OF INDIAN VOCABULARIES RECEIVED FROM THE WHEELER EXPEDITION.

1. Appendix to vocabularies of seven Indian languages.
2. Shoshone.
3. Pi-Ute.
4. Pah-Ute.
5. Pah-Ute.
6. Ute and Pah-vauts.
7. Mojavé.
8. Hualapais.
9. Ute.
10. Ar-i-vai-pa.
11. Acoma Pueblo Indians.
12. Gohun, (Tonto-Apaches.)
13. Shoshone.
14. Isletta, (Pueblo.)
15. Tehua, (Pueblo.)
16. Apache.
17. Moquis.
18. Navajo.
19. Vallatoa, (Gomez, Pueblo.)

CIRCULAR IN REGARD TO THE DISEASE KNOWN AS "CHOREA."

SMITHSONIAN INSTITUTION,
Washington, D. C., January 1, 1875.

Dr. S. Weir Mitchell, an eminent physician and physiologist of Philadelphia, asks the assistance of the Smithsonian Institution in obtaining any facts in regard to the disease known as chorea, or Saint Vitus's dance, and for this purpose has prepared the accompanying series of questions.

The special object of the inquiry is to ascertain whether the assertion that black children are not affected with this disease is correct.

Any data on this subject may be addressed to either the Smithsonian Institution, Washington, D. C., or Dr. S. Weir Mitchell, 1332 Walnut street, Philadelphia.

As *early* information as possible is desired.

Respectfully,

JOSEPH HENRY,
Director Smithsonian Institution.

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1. To what extent do you see chorea (of childhood) among whites?
2. Is it found more in one locality than another?
3. At what season do the attacks come?
4. How often have you seen chorea in blacks of pure breed? If possible, give cases.
5. How common is it in mulattoes?

If you can get answers from other physicians, in addition to your own, it will be desirable.

S. WEIR MITCHELL, M. D.

LITERARY AND SCIENTIFIC EXCHANGES.

Table showing the statistics of the exchanges in 1874.

Agent and country.	Number of boxes.	Bulk in cubic feet.	Weight in pounds.
Royal Swedish Academy of Sciences, Stockholm:			
Sweden	5	35	1,050
Royal Danish Society of Copenhagen:			
Denmark and Iceland	4	30	900
Royal University of Norway, Christiania:			
Norway	3	20	600
L. Watkins & Co., St. Petersburg:			
Russia	7	50	1,500
Frederic Müller, Amsterdam:			
Belgium	5	35	1,050
Prof. Von Baumhauer, Bureau Scientifique Central Néerlandais, Harlem:			
Holland and Batavia	5	35	1,050
Dr. Felix Flügel, Leipzic:			
Germany, Austria, Switzerland, and Greece	40	280	8,400
Gustave Bossange, Paris:			
France and Algiers	11	80	2,400
U. Hoepli, Reale Istituto Lombardi di Scienze e Lettere, Milan:			
Italy	3	20	600
William Wesley, London:			
Great Britain, British possessions in Asia, Africa, &c	30	220	6,600
Other parts of the world:			
Australia	11	80	2,400
Cuba	2	14	420
Brazil	3	20	600
Egypt	1	7	210
Liberia	1	7	210
Total	131	933	27,990

Besides these, smaller packages and live animals were sent to Germany, England, &c. In all, over ten thousand parcels, addressed to institutions and individuals, were distributed.

Government exchanges.

	Boxes.
To German Empire, Berlin	2
To Canada	9
To Japan	5
To Chili	2
Total	18

PACKAGES RECEIVED BY THE SMITHSONIAN INSTITUTION FROM EUROPE, ETC., IN 1874, FOR DISTRIBUTION IN AMERICA.

ALABAMA.	No.
Mobile:	
Barton Academy	1
Tuscaloosa:	
Hospital for the Insane	1
University	1
ARKANSAS.	
Little Rock:	
Institution for Educating the Blind	1
CALIFORNIA.	
Sacramento:	
California State Agricultural Society	1
Geological Survey of California	1
San Francisco:	
Agricultural Society	1
California Academy of Natural Sciences	62
Mayor of the city of San Francisco	1
Mercantile Library Association	2
Stockton:	
State Lunatic Asylum	1
CONNECTICUT.	
Hartford:	
Connecticut State Agricultural Society	1
Retreat for the Insane	1
State Library	2
Young Men's Institute	1
Litchfield:	
Spring Hill Institution	1
Middletown:	
General Hospital for the Insane	1
New Haven:	
American Journal of Science and Arts	54
American Oriental Society	32
Connecticut Academy of Arts and Sciences	86
Museum of Yale College	1
Sheffield Scientific School	1
Yale College	26
Norwich:	
Otis Library	1
DISTRICT OF COLUMBIA.	
Georgetown:	
Georgetown University	7
Washington:	
Agriculture, Department of	138
Board of Indian Commissioners	2
Bureau of Navigation	3
Bureau of Ordnance	4
Bureau of Statistics	23
Census Bureau	9
Coast Survey	62
Columbia Hospital for Women	1
Columbia Institution for the Deaf and Dumb	1
Columbian University	2
Commissioner of Education	2
Engineer Department	2

WASHINGTON, D. C.—Continued.	No.
Geological Survey of the Territories	5
German Reading and Chess Club	1
Hospital for the Insane	1
Howard University	1
Hydrographic Office	8
Interior Department	2
Land-Office	9
Library of Congress	35
Light-House Board	1
Medical Society of the District of Columbia	1
National Academy of Science	47
National Deaf-Mute College	2
Nautical Almanac Office	7
Navy Department	4
Observatory	68
Patent-Office	185
Public schools	2
Signal-Office	22
State Department	3
Surgeon-General's Office	136
Swedish-Norwegian legation	1
Territorial Legislature	1
Treasury Department	5
War Department	11
Young Men's Christian Association	1
FLORIDA.	
Tallahassee:	
Academy	1
GEORGIA.	
Athens:	
Hospital for the Insane	1
Atlanta:	
Atlanta University	1
Milledgeville:	
Hospital for the Insane	1
Oxford:	
Emory College	1
Savannah:	
Chatham Academy	1
ILLINOIS.	
Bloomington:	
Illinois Natural History Society	3
Carbondale:	
Southern Illinois Normal University	6
Chicago:	
Chicago Academy of Sciences	82
Chicago Board of Trade	1
Chicago Public Library	6
Dearborn Observatory	5
Mayor of the city of Chicago	1
Young Men's Association Library	1
Elgin:	
Hospital for the Insane	1
Evanston:	
Northwestern University	1
Jacksonville:	
Illinois Hospital for the Insane	1

Packages received by the Smithsonian Institution, &c.—Continued.

ILLINOIS—Continued.	No.
Peoria:	
Mercantile Library	1
Springfield:	
Academy of Sciences	1
State Library	1
INDIANA.	
Bloomington:	
Indiana University	1
Indianapolis:	
Geological Survey of Indiana	4
Hospital for the Insane	1
Indiana Horticultural Society	1
Indiana Institution for Deaf-Mutes	1
Indiana Institution for Educating the Blind	3
Indiana State Library	3
New Albany:	
Theological Seminary	1
IOWA.	
Burlington:	
Burlington University	1
Des Moines:	
State Library	5
Dubuque:	
German Theological Seminary	1
Independence:	
Hospital for the Insane	1
Iowa City:	
Geological Survey of Iowa	1
Iowa State University	30
Mount Pleasant:	
Hospital for the Insane	1
Wesleyan University	1
KANSAS.	
Lawrence:	
University	1
Ossawatamie:	
Hospital for the Insane	1
Topeka:	
Kansas Academy of Science	1
Kansas State Library	1
KENTUCKY.	
Danville:	
Theological Seminary	1
Frankfort:	
State geologist of Kentucky	1
State Library	1
Third Kentucky Hospital for the Insane	1
Hobb's Station:	
Hospital for the Insane	1
Hopkinsville:	
Second Kentucky Hospital for the Insane	1
Lebanon:	
Saint Mary's College	1

KENTUCKY—Continued.	No.
Lexington:	
First Kentucky Hospital for Insane	2
Kentucky University	1
Russelville:	
Bethel College	1
Shelbyville:	
Observatory of Shelby College	1
LOUISIANA.	
Baton Rouge:	
Academy	1
Clinton:	
Louisiana Insane Asylum	1
New Orleans:	
Lyceum Library	1
Mayor of the city of New Orleans	1
New Orleans Academy of Natural Sciences	40
State Library	9
MAINE.	
Augusta:	
Hospital for the Insane	1
State Library	3
Bangor:	
Commissioner of Fisheries	2
Brunswick:	
Bowdoin College	3
Historical Society of Maine	2
Portland:	
Commissioner of Fisheries	1
Portland Society of Natural History	36
Waterville:	
Waterville College	2
MARYLAND.	
Annapolis:	
Maryland State Library	1
Baltimore:	
Loyola College	1
Maryland Historical Society	3
Maryland Institute	3
Mayor of the city of Baltimore	1
Mercantile Library	1
Newton University	1
Odd Fellows' Library	1
Peabody Institute	7
Saint Mary's College	1
Catonsville:	
Maryland Hospital	1
Rockville:	
Rockville Academy	1
MASSACHUSETTS.	
Amherst:	
Amherst College	3
Andover:	
Theological Seminary	1
Boston:	
American Academy of Arts and Sciences	154
American Social Science Association	4
American Statistical Association	10
American Unitarian Association	2
Board of State Charities	1

Packages received by the Smithsonian Institution, &c.—Continued.

BOSTON, MASS.—Continued.	No.
Boston Athenæum	3
Boston Hospital	2
Boston Hospital for the Insane	2
Boston Society of Natural History	220
Bowditch Library	1
Bureau of Statistics of Labor	1
Christian Examiner	1
Christian Register	2
Gynæcological Society	1
House of Correction	1
McClean Hospital for the Insane	1
Massachusetts Historical Society	13
Massachusetts State Library	10
Mayor of the city of Boston	1
Medical Society	1
Mercantile Library	1
New England Historic Genealogical Society	4
Perkins Institution for the Blind	3
Public Library	26
Cambridge:	
Athenæum	1
Harvard College	32
Harvard College Herbarium	1
Harvard College Observatory	31
Law School Library	1
Museum of Comparative Zoology	92
Theological School Library	1
Jamaica Plain:	
Bussey Institution	16
Newton Centre:	
Newton Theological Institute	1
Northampton:	
Clarke Institution for Deaf-Mutes	1
Salem:	
American Association for the Advancement of Science	33
American Naturalist	2
Essex Institute	100
Peabody Academy of Science	78
Taunton:	
Hospital for the Insane	1
Williamstown:	
Williams College	1
Worcester:	
American Antiquarian Society	24
Free Institute of Technology	2
Hospital for the Insane	1
Worcester Academy	1
MICHIGAN.	
Ann Arbor:	
Observatory	7
University	1
Detroit:	
Michigan State Agricultural Society	7
Public Library	1
Review of Medicine and Pharmacy	3
Saint Philip's College	1
Kalamazoo:	
Hospital for the Insane	1
Lansing:	
Michigan State Library	2

MINNESOTA.	No.
Minneapolis:	
Minnesota Academy of Natural Sciences	3
Saint Paul:	
Chamber of Commerce	1
Minnesota Historical Society	10
Minnesota State Library	1
Saint Peters:	
Hospital for the Insane	1
MISSISSIPPI.	
Clinton:	
Mississippi College	1
Jackson:	
Hospital for the Insane	2
Oxford:	
University	1
MISSOURI.	
Columbia:	
University of Missouri	1
Fulton:	
Hospital for the Insane	1
Saint Louis:	
County Hospital for the Insane	1
Hospital for the Insane, (St. Vincent's)	1
Law Library	1
Mayor of the city of Saint Louis	1
Public School Library	1
Saint Louis Academy of Science	92
State Board of Agriculture	2
State Bureau of Geology and Mines	1
University of Saint Louis	3
NEBRASKA.	
Omaha:	
Hospital for the Insane	1
NEW HAMPSHIRE.	
Concord:	
Hospital for the Insane	1
New Hampshire Historical Society	2
State Library	1
Exeter:	
Phillips's Exeter Academy	1
Hanover:	
Dartmouth College	2
Dartmouth Observatory	1
Manchester:	
City Library	1
NEW JERSEY.	
Burlington:	
Burlington College	1
Hoboken:	
Stevens Institute of Technology	1
New Brunswick:	
Geological Survey of New Jersey	7
Princeton:	
College of New Jersey	5
Salem:	
Salem Academy	1
Trenton:	
State Insane Hospital	1

Packages received by the Smithsonian Institution, &c.—Continued.

NEW YORK.	No.
Albany:	
Albany Institute	18
Dudley Observatory	22
Insurance Department	1
New York State Agricultural Society	25
New York State Library	43
New York State Medical Society	2
New York State Museum of Natural History	8
New York State University	5
State Board of Charities	1
Auburn:	
Criminal Hospital for the Insane	1
Theological Seminary	1
Blackwell's Island:	
City Hospital for the Insane	1
Brooklyn:	
Mercantile Library	1
Buffalo:	
Buffalo Society of Natural Sciences	31
Grosvenor Library	1
Institution for the Deaf and Dumb	1
Medical and Surgical Journal	1
Young Men's Association	1
Canton:	
Saint Lawrence University	1
Clinton:	
Litchfield Observatory of Hamilton College	3
Flatbush:	
Kings County Hospital for the Insane,	1
Hamilton:	
Madison University	1
Ithaca:	
Cornell College	4
Jamestown:	
Jamestown Microscopical Society	4
Lima:	
Wesleyan Seminary	1
Newburgh:	
Theological Seminary of the Associate Reformed Church	1
New York:	
American Bible Society	1
American Bureau of Mines	1
American Chemist	6
American Geographical and Statistical Society	54
American Institute	34
American Institute of Architects	4
American Museum of Natural History	12
American Society of Civil Engineers	20
Anthropological Institute of New York	20
Apprentices' Library	1
Astor Library	16
Bavarian consulate	1
Bloomingdale Hospital for the Insane	1
City Hospital for the Insane	1
Columbia College	1
Engineering and Mining Journal	15
Episcopal Theological Seminary	1

NEW YORK, N. Y.—Continued.	No.
Institution for the Blind	2
Journal of Mining and Engineering	1
Journal of Psychological Medicine	1
Liberal Christian	2
Lyceum of Natural History	97
Manufacturer and Builder	7
Mayor of New York	1
Medical Journal	1
Medical Record	1
Mercantile Library Association	3
Metropolitan Board of Health	1
New York Academy of Medicine	4
New York Handel-Zeitung	1
New York Historical Society	2
New York Tribune	1
Observatory	1
Prison Association	1
Royal Swedish-Norwegian consulate	1
Sanitarian	10
School of Mines	9
Union Theological Seminary	1
United States Sanitary Commission	10
University of the city of New York	4
Poughkeepsie:	
Hudson River Insane Hospital	1
Vassar College	2
Randall's Island:	
House of Refuge	1
Rochester:	
Theological Seminary	1
University	1
Schenectady:	
Union College	3
Troy:	
Marshall Infirmary	1
Utica:	
State Lunatic Asylum	1
Ward's Island:	
Ward's Island Emigrant Hospital for the Insane	1
NORTH CAROLINA.	
Chapel Hill:	
University	1
Davidson College:	
College Library	1
Raleigh:	
Hospital for the Insane	1
Trinity College:	
Theological School	1
OHIO.	
Athens:	
Ohio University	1
Carthage:	
Longview Hospital for the Insane	1
Cincinnati:	
Astronomical Observatory	18
Hamilton County Lunatic Asylum	1
Mayor of the city of Cincinnati	1
Mercantile Library Association	2
Ohio Mechanics' Institute	1

Packages received by the Smithsonian Institution, &c.—Continued.

CINCINNATI, OHIO—Continued.	No.
Public Library	5
Saint Xavier College	1
Cleveland:	
University	1
Columbus:	
Geological Survey of Ohio	4
Horticultural Society	1
Hospital for the Insane	2
Ohio State Board of Agriculture	60
Ohio State Library	9
Dayton:	
Hospital for the Insane	1
Delaware:	
Ohio Wesleyan University	1
Gambier:	
Kenyon College	1
Granville:	
Dennison University	1
New Athens:	
Franklin College	1
Newburgh:	
North Ohio Lunatic Asylum	1
North Bend:	
Horticultural Society of Ohio	1
Oberlin:	
Oberlin College	1
Springfield:	
Wittenberg College	1
Tiffin:	
Heidelberg College	1
Theological Seminary of the German Reformed Church	1
OREGON.	
Portland:	
Hospital for the Insane	1
PENNSYLVANIA.	
Allegheny:	
Allegheny Observatory	2
Western State Penitentiary of Pennsylvania	1
Western Theological Seminary	1
Danville:	
State Hospital for the Insane	1
Dixmont:	
Western Hospital for the Insane	1
Easton:	
Lafayette College	1
Gettysburgh:	
Theological Seminary	1
Harrisburgh:	
Adjutant General	1
Harrisburgh Academy	1
Medical Society of the State of Pennsylvania	2
State Library	3
Kellyville:	
Woodbrook Retreat	1
Mercersburgh:	
Theological Seminary of the German Reformed Church	1

PENNSYLVANIA—Continued.	No.
Philadelphia:	
Academy of Natural Sciences	197
American Entomological Society	10
American Journal of Conchology	4
American Philosophical Society	119
Board of Public Education	1
Central High School	3
Franklin Institute	42
American Pharmaceutical Association	34
Department for the Insane, Almshouse	1
Friends' Insane Hospital	1
German Society Library	1
Girard College	3
Historical Society of Pennsylvania	4
House of Refuge	1
Library Company	2
Library of Pennsylvania Hospital	3
Mayor of the city of Philadelphia	1
Medical Times	10
Pennsylvania Hospital for the Insane	1
Pennsylvania Institution for the Blind	2
Pennsylvania Institution for the Deaf and Dumb	1
Society for Alleviating the Miseries of Public Prisons	1
University of Pennsylvania	2
Wagner Free Institute of Science	9
Pittsburgh:	
German Library	1
Sharon:	
Observatory	1
South Bethlehem:	
Lehigh University	1
Washington:	
Washington College	1
RHODE ISLAND.	
Providence:	
Athenæum	2
Brown University	3
Butler Hospital for the Insane	1
Rhode Island Historical Society	1
SOUTH CAROLINA.	
Charleston:	
Charleston Library Society	2
Elliott Society of Natural History	18
South Carolina Historical Society	1
Columbia:	
South Carolina College	1
Theological Seminary	1
TENNESSEE.	
Columbia:	
Jackson College	1
Knoxville:	
East Tennessee University	1
Lebanon:	
Cumberland University	1
Maryville:	
Southwest Theological Seminary	1

Packages received by the Smithsonian Institution, &c.—Continued.

TENNESSEE—Continued.	No.
Nashville:	
Hospital for the Insane	1
Institution for the Blind	1
University	1
TEXAS.	
Austin:	
Hospital for the Insane	1
Chappell Hill:	
Soulé University	7
UTAH.	
Salt Lake City:	
University of Deseret	1
VERMONT.	
Bristol:	
Orleans County Society of Natural Sciences	28
Burlington:	
University of Vermont	3
Montpelier:	
State Library	5
VIRGINIA.	
Charlottesville:	
University of Virginia	3
Emory:	
Emory and Henry College	1
Fairfax:	
Theological Seminary	1
Hampden-Sidney:	
Union Theological Seminary	1
Richmond:	
Medical Society of Virginia	1
Richmond College	1
State Library	4
University	1
Staunton:	
Western Insane Hospital	1
Weston:	
West Virginia Hospital for the Insane	1
Williamsburgh:	
Eastern Insane Hospital	1
WISCONSIN.	
Beloit:	
Beloit College	1
Janesville:	
Wisconsin Institution for the Education of the Blind	6
Madison:	
Hospital for the Insane	1
State Historical Society of Wisconsin	6
University of Wisconsin	1
Wisconsin Academy of Sciences, Arts, and Letters	10
Wisconsin State Agricultural Society	16
Milwaukee:	
Catholic Seminary	1
Natural History Society	3

WISCONSIN—Continued.	No.
Neenah:	
Scandinavian Library Association	4
Oshkosh:	
Northern Hospital for the Insane	2
Racine:	
College Library	1
WASHINGTON TERRITORY.	
Steilacoom:	
Insane Asylum	1
BRITISH AMERICA.	
Guelph, Ontario:	
Ontario School of Agriculture	2
Kingston, Ontario:	
Botanical Society of Canada	1
Ottawa, Ontario:	
Academy of Natural Sciences	6
Toronto, Ontario:	
Board of Agriculture	1
Board of Arts and Manufactures	1
Canadian Institute	15
Commissioners of Agriculture and Arts	1
Congregational Theological Institute	1
House of Assembly	2
Knox College	1
Literary and Historical Society	1
Observatory	5
Toronto Globe	2
Trinity College	1
University of Toronto	2
Halifax, Nova Scotia:	
Literary and Scientific Society	1
Nova Scotian Institute of Natural Sciences	11
Charlottetown, Prince Edward Island:	
Hospital for the Insane	1
Chambly, Quebec:	
College Library	1
Lennoxville, Quebec:	
Bishop's College	1
Montreal, Quebec:	
Board of Agriculture and Arts	1
Board of Agriculture of Lower Canada	1
Canadian Entomologist	1
College Library	1
Entomological Society	1
Geological Survey of Canada	14
McGill University	1
Natural History Society	48
Numismatic and Antiquarian Society	1
Saint Mary's College	1
Quebec, Quebec:	
Laval University	1
Literary and Historical Society	9
Seminary of Quebec	1

Packages received by the Smithsonian Institution, &c.—Continued.

INDIVIDUALS.	No.
Abbe, Dr. Cleveland	5
Agassiz, Prof. A	16
Allen, Prof. J. A.	4
Alpine, W. W	2
Alvord, Brig.-Gen. Benj	1
Angerer, A. W	8
Anthony, John G.	2
Babcock, Prof	1
Babington, Prof. C	1
Baird, Prof. H. M	1
Baird, Prof. S. F	58
Baker, Dr. Joseph	1
Bancroft, Hon. George	1
Bannister, Dr. Henry M	1
Barker, Dr. Fordyce	1
Barlow, Hon. Francis C	1
Barnard, General J. G	2
Barnard, Prof. F. A. P	1
Bebb, M. S	2
Bessels, Dr. Emil	1
Bethune, Rev. J. S	3
Binney, W. G	5
Blake, Prof. W. P	2
Bland, Thomas	2
Blodget, L	1
Boardman, George A	1
Bolander, Prof. H. N	2
Borges, A. P. De Carvalho	1
Bowers, Rev. S	1
Brendel, Dr. F	2
Brewer, Dr. T. M	1
Brush, Prof. G. J	8
Buckland, George	1
Buckley, Dr	1
Burbank, Prof. L. S	1
Campbell, Prof. John	1
Canby, W. N	4
Carey, Henry C	2
Carpenter, Dr. P. P	3
Chain, J. A	1
Chandler, Prof. C. F	2
Chase, Phiny Earl	1
Chickering, Prof. J. W	1
Clarke, J. L	1
Clarke, Prof. F. W	1
Coffin, Prof. J. H. C	3
Conrad, T. A.	1
Cook, Prof. George H	5
Cooper, Dr. J. G	1
Cope, Prof. E. D	8
Coues, Dr. Elliott	13
Cox, E. T	10
Curtis, Dr. Josiah	1
Curtis, Rev. A	1
Curtiss, Dr. T. B	1
Cutting, Hiram B	1
Cutts, R. D	2
Dall, W. H	8
Dana, Prof. J. D	48
Daniels, Dr	1
Dart, General W	1
Davids, H	1
Dawson, Prof. J. W	5
Dodge, Charles R	1
Draper, Dr. Henry	4

INDIVIDUALS—Continued.	No.
Eastman, Prof	1
Eaton, Dr. Daniel E	2
Edwards, H. W	2
Egleston, Prof. T	4
Elliott, E. B	1
Ellis, J. B	1
Emory, General W. H	1
Endlich, Dr. F. M	2
Engelmann, Dr. Geo	7
Ericsson, Capt. John	1
Fisher, Dr. G. J	2
Foreman, Dr. E	2
Frémont, General J. C	5
Frich, Rev. J. B	2
Gabb, William	1
Graham, Col	1
Gale, Dr. L. D	1
Gardner, Jas. A	1
Geelmuyden, Rev	2
Genth, Dr. F. A	3
Gerard, W. R	1
Gilbert, G. K	3
Gill, Prof. Theo	14
Glover, Prof. T	1
Goodall, G. L	1
Goode, G. Brown	4
Gould, Dr. B. A	1
Grant, Gen. U. S., President U. S	2
Gray, Prof. Asa	28
Greve, T	1
Griffin, G. W	1
Grinnell, Henry	4
Gross, Dr. S. W	1
Grote, A. R	1
Guyot, Prof. A	9
Hagen, Albert D	1
Hagen, Prof. H	7
Haldeman, Prof. S. S	1
Hall, Brigham	1
Hall, Prof. Asaph	1
Hall, Prof. Jas	19
Halvorsen, Rev. H	2
Harper & Brothers	1
Hart, Prof. John S	1
Hayden, Dr. F. V	61
Hedrick, B. S	1
Henry, Prof. Jos	26
Hilgard, Prof. E. W	2
Hilgard, Prof. J. E	1
Hill, G. W	1
Hinrichs, Prof. G	29
Hitchcock, Prof	1
Hitchcock, Prof. E	1
Hitz, J	1
Hjort, Rev. O. J	2
Hoar, Judge E. R	1
Hodge, Rev. Prof	1
Holden, Prof. E. G	3
Holden, William	2
Hooper, T	1
Horn, Dr. G. H	3
Hough, Prof. F. B	2
Howe, Dr. S. G	1
Howell, S. B	2
Humphreys, General A. A	3

Packages received by the Smithsonian Institution, &c.—Continued.

INDIVIDUALS—Continued.	No.
Hunt, T. Sterry	5
Hyatt, Prof. A	1
Jacobson, Rev. A	2
Jarvis, Dr. Edward	30
Jewett, Col. E	4
Kennedy, J. G. C	1
Kerr, Prof. W. C	1
King, Clarence	4
Kingston, Prof. G. C	3
Kirchley, Otto	1
Kirchof, Theodore	1
Klippart, John H	1
Koren, Rev. V	2
Krohn, Rev. J	1
Langley, Prof	1
Larsen, Prof. L	2
Lawrence, G. N	3
Lea, Dr. Isaac	18
Le Baron, William	1
Le Conte, Dr. John L	18
Leidy, Dr. Joseph	14
Leonard, Prof. T. M	1
Lesley, Prof. J. P	2
Lesquereux, Prof. L	3
Lintner, J. H	1
Logan, Sir W. E	4
Loomis, Prof. E	9
Lovering, Prof. J	3
Lyman, Theodore	3
Maack, Dr. G. A	1
MacIntyre, T	1
Magelsen, Rev. C. F	4
Magelson, Rev. Chas	2
Marion, Prof. J	12
Marsh, Prof. O. C	7
Matile, G. A	1
McChesney, J. H	2
McMasters, Æneas	1
McMurtrie, Dr. W	1
Meek, F. B	29
Meigs, Dr. J. A	2
Milner, J. W	1
Mitchell, Maria	1
Mohr, Charles	1
Morgan, L. H	3
Morse, Prof. E. S	1
Morse, Prof. E. T	1
Muns, Rev. J. B	2
Myer, General A. J	10
Newberry, Dr. J. S	8
Newcomb, Prof. S	7
Newton, Prof. H. A	3
Norris, Dr	1
Nourse, Prof. J	1
Nye, Hon. Jas. W	2
Oaker, Hon. L	2
Olmstead, Rev. L	1
Orton, Prof. J	1
Osborne, John W	1
Osten Sacken, Baron	8
Otteson, Rev. J. A	2
Packard, Dr. A. S., jr	14
Paine, Dr. M	1
Palmer, Dr. E	2
Parker, Dr. Peter	2

INDIVIDUALS—Continued.	No.
Peale, Mrs. Franklin	1
Peirce, Prof. B	3
Pennock, Mrs. C	1
Peters, Dr. C. H. F	5
Post, J	1
Pourtales, Count L. F. de	5
Preuss, Rev. H. A	2
Putnam, F. W	3
Ransom, Col. L	1
Rasmussen, Rev. P. A	2
Ray, Dr. Isaac	1
Raymond, Dr. R. W	3
Reque, Rev. S. S	3
Ridgeway, Robert	4
Riley, Chas. V	4
Ritter, Dr. J	1
Robertson, Dr. A	1
Rockwell, A. P	2
Rockwell, Dr. W. H	1
Rogers, Prof. W. B	2
Ross, Dr. Alex. Milton	8
Rothwell, Dr. P	3
Safford, T. H	1
Safford, Prof. J	1
Salisbury, Prof. E. E	2
Sandford, John E	1
Sands, Rear-Admiral B. F	4
Saunders, Wm	2
Schieffelin, H. M	1
Schott, C. A	1
Schuster, Maurice	2
Schwarz-Senborn, Baron	1
Scudder, S. H	3
Silliman, Prof. B	11
Smith, Prof. Hamilton L	3
Smith, Prof. J. Lawrence	1
Smith, Prof. J. J	2
Snow, Dr. E	6
Shaler, Prof. N. S	3
Spinner, Hon. F. E	2
Squier, E. G	2
Stearns, R. E. C	3
Steindachner, Prof	2
Stein, F. R	1
Stenersen, Hon. Olaf	1
Sterling, Clarence	3
Stevenson, James	2
Stone, Ormond	1
Strecker, Hermann	1
Stub, Rev. H. G	2
Swallow, G. C	2
Thomas, Prof. Cyrus	1
Thomson, J. H	4
Thornton, Sir Edward	1
Tietze, Dr. E	3
Torgersen, Rev. T. A	2
True, Dr. N. J	1
Tryon, Dr. G. W., jr	2
Tuckerman, Prof. E	1
Valdeland, Rev. O	2
Vandewond, John	5
Vasey, Prof. George	1
Verrill, Prof. A. E	4
Von Raumbach, Maurice	1
Wagner, Prof. B	1

Packages received by the Smithsonian Institution, &c.—Continued.

INDIVIDUALS—Continued.	No.	INDIVIDUALS—Continued.	No.
Waterhouse, Dr. A	1	Wilkes, Admiral Chas	1
Watson, Prof. J. C	1	Williamson, Prof. J. T	1
Watson, Sereno	1	Winchell, Prof. A	7
Weimuth, T	1	Winchell, Prof. N. H	1
Wells, Hon. David A	1	Winlock, Prof. J	2
Wells, Walter	1	Wood, Dr. Horatio C	1
Western & Co	3	Woodbridge, W. C	1
Wheatley, Chas. M	1	Woodward, Dr. J. J	6
Wheeler, Lieut. G. M	1	Woodworth, Dr. John M	1
White, Dr. C. A	4	Worthen, Prof. A. H	9
Whitney, Prof. J. D	13	Wulfsberg, Rev. E	2
Whitney, Prof. W. D	14	Yarrow, Dr. H	1
Whymper, F	1	Young, Clarence B	9
Williams, Duane	1	Young, Hon. E	1
Williamson, J. A	1	Young, Prof. C. A	1

RECAPITULATION.

Total addresses of institutions	462
Total addresses of individuals	288
	750
Total number of parcels to institutions	3, 221
Total number of parcels to individuals	1, 105
	4, 326

CLASSIFIED RECORD OF MISCELLANEOUS METEOROLOGICAL MATERIAL PRESERVED IN THE SMITHSONIAN INSTITUTION.

[For list of regular monthly reports see report for 1873.]

AURORAS.

Auroral observations made at Ogdensburgh, New York, 1852–'54.

Aurora observed at Bangor, Me., December, 1851.

Aurora observed at Boston August 20, 1851.

Aurora observed at Camden, Me., September 10, 1854.

Auroras observed at Dartmouth College, N. H., July 12, 1853–March 16, 1854.

Auroras observed at sea 1848–'53.

Auroral records, 1849–'53.

Notices of auroras, 1847–'59.

Sketch of aurora observed at Washington July 22, 1868.

Alexander, Prof. S.—Sketch of aurora observed at Princeton, N. J.

Andrews, Luman.—Account of aurora observed October 14, 1870, at Southington, Conn.

Ashby, M. V.—Notice of aurora observed August 8, 1872, at Afton, Iowa.

Astrop, R. F.—Aurora observed in Brunswick County, April 7, 1847; auroral display September 29, 1851.

Averbeck, A.—Aurora observed July 9, 1872, at Saint Louis, Mo.

Babcock, E.—Account of aurora observed August 8, 1872, at Boonsborough, Iowa.

Bache, Prof.—Aurora observed at Bath, Me., September 29, 1852.

Barnard, A. D.—Aurora observed at San Buenaventura, Cal., June 17, 1870.

Bassnet, Thomas.—Auroras seen at Ottawa May 24 and 25, 1853, May 29, 1840.

Bessey, Charles E.—Auroras observed at Ames, Iowa, in June, 1871.

Bidwell, Dr. E. C.—Auroras observed at Keene, Ohio, February 19, March 1, 1852.

Birney, J. G.—Auroras observed at Lower Saginaw, Mich., in April, 1849.

Blodgett, Lorin.—Aurora observed at Sugar Grove, Pa., September 29, 1851.

Bowman, John.—Auroras observed at Baldwinsville October 4, 1855.

Brewer, W. H.—Auroras observed at Ovid, N. Y., from December, 1852, to May, 1854.

Brewster, Alfred.—Notice of aurora observed at Tamworth, N. H., July 17, 1872.

Brown, H. H.—Aurora observed at Dakota City, Nebr., July 10, 1868.

Buckland, D.—Aurora observed at Brandon, Vt., May 2, 1855.

Campbell, C.—Auroras observed at Moose Factory, June, 1850.

Clarke, John.—Auroras observed at Bowling Green, Ohio, in 1872.

Clift, Henry A.—Harbor Grace, N. F., account of February aurora; auroral notes for July, 1872; aurora observed August 25, 1872.

Cobb, W. H.—Aurora observed at Wellsborough, Pa., April 15, 1869; display of auroras observed in Philadelphia August 3, 1872.

Couch, E. D.—Auroras observed at Newfield, N. J., in 1840.

Curtis, W. W.—Auroras observed at Rocky Run, Wis., in 1872.

Dayton, E. A.—Auroras observed at Madrid, N. Y., March, 1849.

De Haven, Lieutenant.—Auroras observed during Arctic expedition 1850–'51.

Dewey, C.—Auroras observed at Rochester, N. Y., September, 1851, February, 1852.

Dolan.—Account of aurora observed in New York April 15, 1869.

Edwards, J.—Aurora observed at Lima, Pa, March, 1849, September, 1851.

Fairbanks, G. W.—Auroras observed at Washington, D. C., September 29, 1851.

Fairchild, Jno. P.—Auroras observed at Seneca Falls, N. Y., September, 1851.

Favel, P. F.—Notes relative à la formation des aurore boreales.

Foster, Wm., jr.—Aurora observed at Providence, R. I., April 15, 1869.

Garland, J. G.—Aurora observed at Biddeford, Me., February 19, 1852.

Gibbes, Lewis R.—Aurora observed at Charleston, S. C., September 29, 1851.

Gibbon, Lardner.—Account of aurora of August 7, 1872.

Grant, Benjamin.—Aurora observed at Erie, Pa., August 11, 1869.

Groneweg, L.—Auroras observed at Germantown, Ohio, April, 1852.

Guest, W. E.—Auroras observed at Ogdensburgh, N. Y., February, 1850–September, 1851.

Haas, Henry.—Register of all the auroras observed at Depauville, N. Y., from 1866 to 1872.

Hall, Joel S.—Auroras observed at Athens, Ill., September 29, 1851.

Haywood, John.—Westerville, Ohio, auroras seen in August and October, 1872.

Herrick, E. C.—Aurora observed at New Haven, Conn., June 11, 1852.

Herrick, J.—Auroras observed at Hampden, Me., November 18, 1848.

Hoadley, C. J.—Auroras observed at Hartford, Conn., May 12, 1849.

Holcomb, Amasa.—Auroras observed at Southwick, Mass., 1837-1853; auroras observed at Southwick, Mass., March and April, 1850.

Horr, Asa.—Auroras observed at Dubuque, Iowa, September 29, 1851.

Hotchkiss, J.—Auroras observed at Mossy Creek, Va., February 19, 1852.

Hough, Dr. F. B.—Auroras observed at Somerville, N. Y., 1837–1851.

Hyde, Thos. C. P.—Aurora observed at East Windsor Hill, Conn., June 11, 1852.

Jennings, S. K.—Auroras observed at Erie, Ala., September 29, 1851.

Johnson, E. W.—Aurora observed November 17, 1849, at Grand Rapids, Mich.

Jones, C. P.—Auroras observed at Valley Forge, Pa., January 19, 1852.

Joslyn, H.—Auroras observed at Waukegan, Ill., April 13, 1849.

Kidder, L. D.—Aurora observed at Whitfield, N. H., October 13, 1869.

Lapham, I. A.—Auroras observed at Milwaukee, Wis., February 15, 1852.

Lefferts, John.—Auroras observed at Lodi, N. Y., February 19, 1852.

Lefroy, J. H.—Abstracts of auroral observations; auroral notes; auroras observed at Toronto, August, 1849; general register of appearances of auroras borealis, &c., from January 1, 1848, to May 31, 1853. Second report of auroral observations, 1850–'51.

Lewis, B. B.—Theory of auroras.

Loomis, Elias.—The aurora borealis, or polar light, its phenomena and laws.

McClintock.—Auroras observed May 19, 1870.

Major, J.—List of books and ships' logs examined for auroras.

Marks, Corrydon.—Auroras observed at Manchester, Pa., September 1849–February, 1851.

Marsh, C. C.—Auroras observed at Oswego, N. Y., February 19, 1852.

Mead, S. B.—Auroras observed at Augusta, Ill., February 18 and September, 1851; January 19, 1852; May 24, 1853.

Mitchell, Hon. W.—Auroras observed at Nantucket, Mass., 1844–1853.

Moss, C. S.—Aurora observed at Amboy, Ill., April 2, 1869.

Mudge, B. F.—Aurora observed at Manhattan, Kans., August 8, 1872.

Newkirk, B. M.—Auroras observed at Laporte, Ind.

Osborne, Capt. Sherard.—Remarks on auroral light in Arctic Zone.

Peelor, David.—Auroras observed at Johnstown, Pa., October 26, 1870.

Phelps, R. H.—Auroras observed at Windsor, Conn., February 19, 1852.

Pinkham, M. S.—Aurora observed at Millbridge, Me., February 4, 1872.

Poole, Henry.—Auroras observed at Albion Mines, N. S., in 1850; resemblance of reflected light to aurora.

Prescott, W.—Auroras observed at Concord, N. H.

Prince, Geo.—Auroras observed at Thomaston, Me., March, April, 1850.

Redding, Thos. B.—Auroral display at Newcastle, Ind., June 18, 1871.

Rejusar, Thomas.—Aurora observed at Newton, N. J., April 15, 1869.

Rice, H.—Auroras observed at Attleborough, Mass., January, 1851.

Robertson, Thos.—Auroras observed April, 1850.

Roulston, Andrew.—Auroras observed at Freeport, Pa., in 1849, 1850.

Salisbury, O. E.—Auroras observed at Buffalo, N. Y., in 1853.

Shields, Robert.—Auroras observed at Belle Centre, Ohio, September, 1853.

Simmons, G.—Auroras observed at Lachine in September, 1850.

Sisson, Rodman.—Aurora observed at Factoryville, Pa., March 19, 1868; auroras observed at Scranton, Pa., October, 1871; show of auroras August 3, 1872.

Smallwood, Doctor.—Auroras observed at Saint Martin's, February 19, 1852.

Steele, G. E.—Aurora observed at Homestead, Mich., August 4, 1865.

Steiner, Dr. Lewis H.—Auroras observed at Frederick, Md., September 29, 1851.

Stevens, Dr. R. P.—Auroras observed at Ceres, Pa., April 6 and 8, 1870.

Stewart, A. P.—Aurora observed at Lebanon, Tenn., September 29, 1851.

Swift, Lewis.—Aurora observed at Marathon, N. Y., April 16, 1869.

Warne, Geo.—Auroras observed at Independence, Iowa, August, 1872; auroras observed in 1872.

Whitcomb, Thomas M.—Auroral display of July 21, 1871, Union Ridge, W. T.

Winchell, A.—Auroras observed in Eutaw, Ala., September 29, 1851.

Wing, M. E.—Auroras observed January 31 and February 7, 1872.

Withrow, Thomas F.—Auroras observed at Station Horner, Ohio, February 17, 1852.

Young, J. A.—Account of aurora observed September 29, 1857, at Camden, S. C.

INSTRUMENTS.

Apparatus for recording earthquakes.

Comparative value of certain varieties of cloth for covering the wet bulb of the hygrometer.

Diagram of rain-gauge used at Snowville, Va.

Lippincott's vapor index, a psychrometrical calculator.

Remarks upon the barometer and rules for its observation.

Rules to be observed in management of typo-barograph.

Woodruff's portable barometer.

Storm rain-gauge designed by G. J. Symons for observing rate of fall.

Beck.—Description of recording barographs, thermographs, and anemographs.

Craig, B. F.—Comparison of ten of Green's barometers.

Fenton, Elisha.—Description of hygrometer.

Hough, G. W.—Description of automatic registry and printing barometer.

Roedel, W. D.—Sketch of self-registering thermometer.

Stephenson, W. J.—Account of electro-magnetic indicator.

Sternberg, George M.—Improved anemometer.

Wait, S. E.—Sketch of proposed snow gauge.

Williams, R. G.—Comparison of Mason's hygrometer with Boehlen and Staehlon's.

METEORS.

Alaska.—Account of meteors at Sitka, 1868, Dwight Hurlbut, and J. J. Blakemore.

Aubier, J. M.—Meteors observed from Saint Xavier's College, New York, November 14, 1864.

Barnard, A. D.—Meteor observed October 20, 1873, at Ventura, Cal.

Beckwith, W.—Meteors observed at Olathe, Kans., November, 1866.

Betts, Henry.—Account of meteors observed at Weston, Conn., 1867.

Boehmer, George H.—August meteors observed in Colorado Springs, Colo., 1873.

Boerner, Charles G.—Meteors observed at Vevay, Ind., October 24, November 10, 12, 1870.

Meteoric observations at Vevay, Ind., 1868.

Observations of August shower of meteors, 1871.

Brewer, F. P.—Meteors observed at Raleigh, N. C., November, 1866.

Carleton, General J. H.—Account of meteorites in Mexico.

Chappelsmith, John.—Meteors observed at New Harmony, Ind., November, 1866–'67.

Chase, Milton.—Meteors observed at Kalamazoo, Mich., November, 1866.

Clingman, T. L.—Account of meteor observed at Washington, August 2, 1860.

Coles, Isaac.—Meteors observed at Glen Cove, November, 1866.

Deckner, Fred.—Meteors observed at Atlanta, Ga., November, 1866.

Delaney, John.—Account of meteorite observed at Saint John's, N. F.

Edi, James.—Meteors observed at Vienna, Wis., November, 1866.

Fendler, A.—Meteors observed at Allenton, Mo., November, 1866.

Fergus, Thomas H.—Meteors observed at West Chester, Pa., November, 1866.

Forshey, C. G.—Meteors observed at Galveston, Tex., November, 1866.

Gantt, Dr. W. H.—Meteors observed at Chapel Hill, Tex., November, 1866.

Gardiner, J. H.—Meteors observed at Newburgh, N. Y., November, 1866.

Gibbs, George.—Meteors observed at Richfield Springs, N. Y., August 24, 1869.

Grinnan, A. G.—Meteors observed at Orange, Va., November 10, 1866.

Hance, E.—Meteors observed ta Falsington, Pa., November, 1866.

Holmes, E. D.—Meteors observed at Grand Raipds, Mich., November 13, 1866.

Hopkins, A.—Meteors observed at Williamstown, Mass., November 12, 13, 1866.

Horr, Dr. Asa.—Meteors at observed, Dubuque, Iowa, November, 1866.

Hudson, A. T.—Meteors observed at Lyons, Iowa, November, 1866.

Hyatt, A.—Meteors observed at Salem, Mass., September 29, 1868.

Ingram, J.—Meteors observed at Vineland, N. J., August 24, 1869.

Johnson, Professor J.—Meteors observed at Middletown, Conn., November, 1866.

Keenan, T. J. R.—Account of meteors observed at Bahala, Miss.

Knight, R. T.—Account of meteors observed at Philadelphia, August 24, 1869.

Lapham, I. A.—Meteors observed at Milwaukee, Wis., November, 1866, 1867.

McClune, James.—Meteoric shower at Philadelphia, November 14, 1867.

Major, J.—List of books and ship's logs examined for meteors.

Martin, Samuel D.—Meteors observed in Clarke County, Kentucky, November, 1866.

Moore, Albert.—Meteors observed at Grenada, Miss., November, 1866.

Morris, O. W.—Meteors observed in New York, November 13, 1866.

Mudge, B. F.—Meteors observed at Manhattan, Kans., November, 1866.

Nason, Elias.—Meteors observed at North Billerica, Mass., November, 1866.

Newton, Professor.—November meteors.

Parker, J. D.—meteoric display at Steuben, Me., November, 1864, 1866, 1867.

Parkhurst, H. M.—Meteors observed at Brooklyn, Mo., 1866.

Pratt, W. H.—Meteors observed November 14, 1868, at Davenport, Iowa.

Raser, John Heyl.—Meteors observed at Reading, Pa., November, 1866.

Redding, Thomas B.—Meteors observed at Newcastle, Ind., November, 1864.

Richards, W. M.—Meteors observed at Berlin, Wis., November, 1866.

Robinson, A.—Meteors observed at Androscoggin, Me., November, 1866.

Rogers, F. M.—Meteors observed at Throg's Neck, N. Y., November 27, 1864.

Smith, E. A.—Meteors observed at Moriches, N. Y., November, 1866.

Smith, Eli.—Meteors observed at Emmittsburg, Md., November, 1866.

Snow, F. H.—Meteoric shower at Lawrence, Kans., November 14, 1867.

Spaulding, A.—Meteors observed at Aurora, Ill., November, 1866.

Spencer, W. C.—Meteors observed at Dubois, Ill., November, 1866.

Spera, W. H.—Meteors observed at Ephrata, Pa., November, 1867.

Stephenson, Rev. James.—Meteors observed at Saint Inigoes, Md., November, 1876.

Trembly, J. B.—Meteors observed at Toledo, Ohio, November, 1866.

True, H. A.—Meteors observed at Marion, Ohio, November, 1866.

Turner, Ernest.—Account of meteor observed at Point Pleasant, La., June 29, 1872.

Tutwiler, H.—Account of meteoric shower observed at Green Springs, Ala., November 14, 1868.

Washington, D. C.—Account of meteors observed at the United States Naval Observatory, 1868.

West, Silas.—Meteors observed at Cornish, Me., November, 1866.

Wheeler, John T.—Meteors observed at Concord, N. H., November, 1866.

Wilbur, B. F.—Meteors observed at West Waterville, November, 1866.

Williams, M. G.—Meteors observed at Urbana, Ohio, November, 1866.

Winger, Martin.—Meteors observed at Wooster, Ohio, November, 1866.

RAIN.

Depth of rain collected in several rain-gauges during the storm of October, 1869.

Extract from the meteorological registers of the Surgeon-General's Office from January, 1860, to January, 1867, giving summaries of amount of rain and melted snow at meteorological stations in the western part of the United States.

Influence of the weather in the production of rain.

Adams, J. F.—Account of extraordinary rain-storm at Macon, Ga., October 2, 1868.

Bache, D.—Account of hail-storm at San Antonio, Tex., May, 1868.

Bartlett, Jefferson.—Snow-fall in West Lebanon, Ind., winter of 1869.

Berlandier, J. Louis.—Rain-fall at Matamoras, Mex., 1843–'51.

Bermuda.—Quantity of rain-fall at Ireland Island 1860–'62.

Blackwell, Thos.—Return showing percentage of rain due to winds bearing rain from surrounding regions. Observations made at Montreal 1859–'60.

Branley, E. H.—Rain-fall at Amesville, Ohio, January, 1869.

Cambridge, Mass.—Rain-fall 1855–67.

Canton, Mo.—Rain-fall in 1870.

Chase, Pliny E.—Cyclical rain-fall at San Francisco. Rain-curves. Recent monthly rain-fall in the United States. Remarks on the fall of rain as affected by the moon.

Clark, Dr. Jas. F.—Effect of battles on rain, observed during the war.

Cockburn, S.—Rain-fall in Balize, Honduras, 1862–'68.

Cocke, T. R.—Amount of rain-fall October, 1871, in Victoria County, Texas.

Crosier, Adam.—Mean monthly rain-fall at Laconia, Ind., 1866–69.

Cunningham, Geo. A.—Rain-table 1841–'68, at Lunenburgh, Mass.

Curle, T. J.—Observations showing that anvil-shaped clouds indicate rain.

Davidson, S.—Rain-fall at Sitka, Alaska, May, 1866, April, 1867.

Draper Jos.—Rain-fall at Worcester, 1860.

Ewing, Chas. G.—Quantities of rain that fell in each month, 1855–'70.

Foote, H. S.—Report of rain-fall, January–June, 1869.

Gibbs, Geo.—Account of deluge in Patapsco and Monocacy.

Gilmanton, N. H.—Record of snow, rain, &c., 1838–'64.

Grant, W. T.—Report of rain-fall at Athens, Ga., September and October, 1872.

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Account of destructive storm, September 6, 1769.

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Capeville.—Statement of temperature, 1870, Emma C. Townsend.

Culpepper.—Temperature, 1869–1872, A. Taliaferro.

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Wytheville.—Meteorological observations, October 31, 1872, J. A. Brown.

Barometer and thermometer curves 1868–1872.

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Cape Disappointment.—Meteorological observations, 1864–'68.

Cathlamet.—Notes for December, 1873, Chas. McCall. Weather notes, September, 1868–September, 1869, December, 1873, Chas. McCall.

Union Ridge.—Weather notes, January–March, 1871, Thos. M. Whitcomb.

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Temperature observations, January–July, 1868, S. J. Stump.

Weather notes, March, April, 1866, W. H. McDowell.

Kanawha Salines.—Depths of rain, April, 1857–April, 1858, W. C. Reynolds. Meteorological observations, 1828–1842, 1856 L. D. S. Ruffner.

Sheets' Mills.—Table showing highest and lowest range of thermometer, 1856–1865, Hendricks Clark.

Weston.—Meteorological reports, 1869–'73, Benjamin Owen. Meteorological report, December, 1873. Temperature observations, May, June, 1870.

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Map of Wisconsin, with lines showing effect of Lake Michigan on temperature, I. A. Lapham.

On the climate of the country bordering on the great North American lakes, with map, I. A. Lapham.

Baysfield.—Meteorological observations, March, 1866, Andrew Tate.

Beaver Dam.—Account of hail-storm, May, 1855, Reuben Smith.

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Detroit.—Annual summary of weather record for 1873, F.W. Higgins.

Hartford.—Meteorological observations, 1859–'62, Hopewell Cox.

Hingham.—Meteorological reports, 1867, John de Lyser.

La Pointe.—Thermometric record, July–September, 1856, Edwin Ellis.

Le Roy.—Remarks on the weather, August, 1873, E. H. Benton.

Manitowoc.—Amount of rain and melted snow, 1863–72, Jacob Lüps. Das Gedeihen der Pflanzen, Jacob Lups. Meteorological table showing the temperature from 1852–1871 inclusive, Jacob Lups. Meteorological observations, October, 1851–December, 1856; Jacob Lups. Meteorological tables, 1852–1866, Jacob Lups.

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San Luis Potosi.—Diagram of temperature observations at 6 a. m. and 2 and 10 p. m.

ECUADOR.

Guayaquil.—Meteorological observations, October, 1868, A. Destruze.

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British Guiana.

Georgetown.—Daily mean of meteorological elements at Georgetown observatory, January–June, 1854, February, 1864, P. Sandeman.

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Paramaribo.—Maximum and minimum temperature, August, 1859, C. J. Hering. Temperature and rain-fall observations, June 6–December 15, 1867, January–July, 1869. Werkundige warmemingen te Paramaribo, 1868–'69.

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Barometrical observations taken on journey to interior, Dr. A. Ernst.

WEST INDIES, ETC.

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Meteorological observations at Saint Michael in 1874, Thos. Hickling.

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Meteorological tables, January, 1841-August, 1845, J. C. Lee.

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Meteorological observations taken at Little Island, Saint Joseph, 1873.

Rain-fall in Barbados, 1872-'73.

Rain-fall and meteorological observations, 1873.

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Abstract of the Royal Engineers' meteorological observations at Bermuda, 1859.

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Havana.—Observaciones meteorologicas, 1842, L. R. Gibbes.

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Up Paak Camp, meteorological observations, January–March, 1856.

ST. CROIX.

Notice of earthquake, March 19, 1868, E. H. Perkins.

ST. MARTIN.

Notice of earthquakes, January, 1869.

MISCELLANEOUS AND UNKNOWN LOCALITIES.

Abstract of logs and observations taken at sea.

Account of meteorological observations in New Granada, Central America, Mexico, and Alabama, A. Cornette.

Curvas correspondientes, de Abril de 1866.

Map of Polar Sea, illustrative of acquired facts, M. S. Fields.

Maximum, minimum, and mean temperature, 1871.

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Meteorological observations, 1870, G. C. Doane.

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Meteorological report of United States frigate United States, April–July, 1844.

Meteorological report of United States revenue steamer Wyanda, May–October, 1868.

Periodical phenomena, 1866.

REPORT OF THE EXECUTIVE COMMITTEE.

The executive committee of the Board of Regents respectfully submit the following report in relation to the funds of the Institution, the receipts and expenditures for the year 1874, and the estimates for the year 1875:

Statement of the fund at the beginning of the year 1875.

The amount originally received as the bequest of James Smithson, of England, deposited in the Treasury of the United States, in accordance with the act of Congress of August 10, 1846	$515,169 00
The residuary legacy of Smithson, received in 1865, deposited in the Treasury of the United States, in accordance with the act of Congress of February 8, 1867	26,210 63
Total bequest of Smithson	541,379 63
Amount deposited in the Treasury of the United States, as authorized by act of Congress of February 8, 1867, derived from savings of income and increase in value of investments	108,620 37
Amount received as the bequest of James Hamilton, of Carlisle, Pa	1,000 00
Total permanent Smithson fund in the Treasury of the United States, bearing interest at 6 per cent., payable semi-annually in gold	651,000 00
In addition to the above there remains of the extra fund from savings, &c., in Virginia bonds and certificates, viz: Consolidated bonds, $58,700; deferred certificates, $29,375.07; fractional certificate, $50.13: total, $88,125.20; now valued at	35,000 00
Cash balance in the United States Treasury at the begining of the year 1875, for current expenses	15,909 99
Amount due from First National Bank, Washington, $4,112.43, (present value unknown)	
Total Smithson funds 15th January, 1875	$701,909 99

The coupons on the Virginia bonds held by the Institution were sold on the 19th May, 1874, by Riggs & Co., with the following result:

\$1,200 Virginia coupons, at $77\frac{1}{8}$	\$925 50
\$2,322 Virginia coupons, at 77	1,787 94
	2,713 44
Less charges	17 61
	\$2,695 83

This amount was deposited with the Treasurer of the United States on account of the current expenses of the Institution for the year.

The value of the Virginia bonds held by the Institution has increased during the year about \$2,000.

Coupons due July 1, 1874, and January 1, 1875, are still uncollected, and will form part of the income for the year 1875.

It was stated in the last report that at the time of the suspension of the First National Bank of Washington, (19th September, 1873,) where the current funds of the Smithsonian had been deposited, there were \$8,224.87 to the credit of the Institution; and that on the 11th of November, 1873, a dividend of 30 per cent., or \$2,467.46, had been received, leaving a balance of \$5,757.41 due. A second dividend on this deposit was made on the 7th of April, of 1874, of \$1,644.97, still leaving \$4,112.43 due the Institution, which it is hoped will be received at least in part during the coming year.

Statement of the receipts and expenditures in 1874:

RECEIPTS.

Interest on \$650,000 from the United States, 6 per cent., gold	\$39,000 00
Interest on \$1,000 from the Hamilton bequest, from 24th February, 1874, to 31st December, 1874	50 88
Premium on gold 30th June, 1874, $110\frac{1}{16}$; and 31st December, 1874, $112\frac{1}{4}$, (less commission)	4,308 35
Interest on Virginia stock, coupons sold, (9th May, 1874).	2,695 83
Twenty per cent. dividend from First National Bank, (7th April, 1874)	1,644 97
Total receipts	47,700 03

EXPENDITURE.

Total expenditure from the Smithson income in 1874	44,016 72
Balance unexpended of the annual income which is included in the cash balance in the Treasury, (\$15,909.99)	3,683 31

Statement of expenditure in detail from the Smithson income, 1874.

	Building.	
Repairs of the building	$3,507 66	
Furniture and fixtures	717 73	
		$4,225 39
	General expenses.	
Meetings of the board	312 87	
Lighting the building	523 15	
Heating the building	305 47	
Postage	81 07	
Stationery	492 64	
Incidentals	817 17	
Salaries and clerk hire	12,730 00	
Purchase of books	457 43	
		15,719 80
	Publications and researches.	
Smithsonian Contributions	7,022 98	
Miscellaneous collections	7,363 67	
Reports	664 92	
Other publications	93 40	
Meteorology and researches	881 97	
Apparatus	1,142 60	
Laboratory	9 10	
Lectures	600 00	
		17,778 64
	Exchanges.	
Literary and scientific exchanges, &c		5,589 89
	Museum.	
Incidentals in addition to Government appropriation		703 00
		$44,016 72

As usual, the Institution has during the past year made temporary advances for the payment of freight on Government collections, purchase of instruments for exploring parties, &c., the repayments of which, together with the amount received from sales of publications, have been deducted from the several items of the foregoing expenditures, as follows:

	Repayments.
From exchanges, repayments for freight, &c	$1,205 14
From postage, repayments	45 45
From researches, repayments	95 76
From Smithsonian Contributions, sales	115 60
From miscellaneous collections, sales	157 67
From salaries, repayment of advance	40 00
From incidentals, sales of old material	7 27
	$1,666 89

The following are the estimates of receipts and appropriations of the Smithson fund for the year 1875:

Estimated receipts.

Interest on the permanent fund, receivable 30th June, 1875, in gold	$19,500	
Interest on the permanent fund, receivable 31st December, 1875, in gold	19,500	
Interest on the Hamilton fund	60	
Probable premium on gold, 10 per cent	3,906	
Interest on Virginia bonds	2,000	
		$44,966

Provisional appropriations.

For building	$2,000	
For general expenses	14,000	
For publications and researches	20,000	
For exchanges	7,000	
For books and apparatus	1,000	
For contingencies	966	
		$44,966

NATIONAL MUSEUM.

The annual appropriation of Congress for the preservation of the Government collections intrusted to the care of the Institution has been continued during the past year, and an additional sum of $10,000 has been granted for the fitting up and completing the cases in the new halls required for these collections.

The latter appropriation has been expended in the construction of walnut table-cases with glass tops and sides, for the exhibition of the smaller ethnological specimens in the upper hall, and for large cases for mammals and fishes in the lower hall. The latter cases have also been so constructed as to serve as bases or platforms for restorations of the megatherium, hadrosaurus, glyptodon, &c., thus utilizing a large space, and forming a very striking and imposing feature of the collections.

The following is a tabular statement of the condition of the Museum funds:

For preservation of the Government collections.

Balance unexpended of appropriation for the fiscal year ending June 30, 1874. (Statutes at Large, vol. 17, p. 518) See Report for 1873, page 145	$7,500 00	
Amount expended to December 31, 1874. (See Museum Journal A, p. 73.)	7,500 00	
Balance		Nothing.

Appropriation for fiscal year ending June 30, 1875. (Statutes, 1874, p. 216)	$20,000 00	
Expenditure from July 1, 1874, to January 11, 1875. (See Museum Journal A, p. 106)	12,011 38	
Balance unexpended		$7,988 62

For fitting up halls for Government collections.

Balance unexpended of appropriation for fiscal year ending June 30, 1874. (Museum Journal A, p. 519)	$5,550 92	
Expenditure on this account in 1874. (Museum Journal A, p. 527)	5,550 92	
Balance		Nothing.

For steam-heating apparatus for Museum.

Balance unexpended of appropriation for fiscal year ending June 30, 1874. (Museum Journal A, p. 533)	3,462 03	
Expenditure on this account in 1874. (Museum Journal A, p. 527)	3,462 03	
Balance		Nothing.

For fitting up and completing cases for collections.

Appropriation for fiscal year ending June 30, 1875. (Statutes, 1874, p. 216)	10,000 00	
Expended on this account in 1874. (Museum Journal A, p. 106)	10,000 00	
Balance		Nothing.

From the above statement it appears that of the congressional appropriations for the National Museum, the only amount unexpended and now available for the collections is $7,982.62. The *estimates* submitted by the Institution to Congress for the fiscal year ending 30th June, 1876, were as follows:

For the preservation of the collections	$25,000 00	
For fitting up and completing the cases	10,000 00	
Total amount required		$35,000 00

We have no reason to doubt that this sum, or the greater part of it, will be appropriated by Congress during the present session.

All the payments on account of the National Museum have been made during the past year, directly by the disbursing officer of the Department of the Interior, on the presentation of vouchers approved by the Secretary of the Smithsonian Institution.

The executive committee have examined five hundred and seventeen receipted vouchers for payments made from the Smithson income during the year 1874, and four hundred and seventy similar vouchers for payments made from the congressional appropriations for the National Museum, making a total number of vouchers of nine hundred and eighty-seven.

All of the vouchers have the approval of the Secretary of the Institution, and a certificate setting forth that the materials and property and services rendered were for the Institution, and to be applied to the purposes specified.

As authorized by a resolution of the board 26th May, 1874, the committee have also examined the account-books of the National Museum and find the balance of $7,988.62 to the credit of the appropriation for the "preservation of the collections" remaining on the 11th January, 1875, to correspond with the certificate of the disbursing clerk of the Department of the Interior.

The quarterly accounts current, bank-book, check-book, and ledger, have also been examined and found to be correct, showing a balance in the care of the Treasurer of the United States 15th January, 1875, of $15,909.99.

Respectfully submitted.

PETER PARKER,
GEO. BANCROFT,
Executive Committee.

WASHINGTON, *January* 23, 1875.

JOURNAL OF PROCEEDINGS OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION.

WASHINGTON, D. C., *January* 20, 1875.

In accordance with a resolution of the Board of Regents, fixing the third Wednesday of January as the time for the commencement of the annual session, a meeting of the Board of Regents was held on Wednesday, 20th of January, 1875, at 7 o'clock p. m., at the Smithsonian Institution.

Present, the Chancellor, Chief-Justice Waite; Hon. Henry Wilson, Vice-President of the United States; Senators H. Hamlin and A. A. Sargent; Representive Hon. E. R. Hoar; Hon. Peter Parker, Prof. Asa Gray, L. L. D., Prof. H. Coppée, L. L. D., Hon. George Bancroft, and Professor Henry, the Secretary.

The minutes of the last meeting were read and approved.

Excuses for non-attendance were received from Prof. Dana, Doctor Maclean, Hon. Mr. Stevenson, and Hon. Mr. Cox.

The Secretary presented the following letter from General Sherman, which was read:

HEADQUARTERS ARMY OF THE UNITED STATES,
Saint Louis, Mo., November 12, 1874.

MY DEAR PROFESSOR: Having removed my headquarters and residence from Washington to Saint Louis, it is proper that I should resign the post I have held for a few years as a Regent of your most honored Institution. I beg, therefore, that you will construe this letter as a tender of my resignation to the Board of Regents, or to such official as can accept the same.

In thus severing my official connection with the Smithsonian, I beg leave to express to you and your associates my sense of the noble task in which you are engaged, and of my earnest prayer that the Institution under your management will continue to fulfil its magnificent design.

A knowledge of science, that is of the laws of nature, is so intimately connected with the advance of higher civilization, that Mr. Smithson displayed unusual wisdom in so endowing his institution that it should give its principal labor to the increase of knowledge, to accumulating and securing new knowledge to be added to the old, which should be a special province of the universities of the whole earth. I therefore coincide with you perfectly in your special construction of the will, and hope that the Regents will continue to construe it literally, as a legacy sacred in its nature and beneficial in the highest degree.

I beg you will assure your associates that among the many causes of regret at leaving Washington, none impresses me more than that which forces me to sever my relations with the Regents of the Smithsonian Institution.

With great respect, your friend and servant,

W. T. SHERMAN,
General.

Prof. JOSEPH HENRY,
Smithsonian Institution, Washington, D. C.

On motion of Dr. Parker, it was

Resolved, That the Secretary of the Institution acknowledge the receipt of the letter from General Sherman, and express to him the high appreciation of the members of the board of his services as a Regent, and their regret at the termination of his official connection with the Institution.

The Secretary stated that Congress had passed a joint resolution electing Hon. George Bancroft, who had recently become a permanent resident of Washington, as Regent to fill the vacancy occasioned by the resignation of General Sherman.

On motion of Mr. Wilson, it was

Resolved, That the vacancy in the EXECUTIVE COMMITTEE, occasioned by the resignation of General Sherman, be filled by the appointment of Hon. GEORGE BANCROFT.

The Secretary presented his annual report of the operations and condition of the Institution, which was read in part. He also presented exhibits of the finances, which were referred to the Executive Committee.

The Secretary stated that the annual accounts had been made up to the 15th of January, the date at which the semi-annual interest was received from the Treasury Department.

Dr. Parker, from the Executive Committee, presented a preliminary report on the condition of the Smithson fund, and the receipts and expenditures for the past year, and stated that all the vouchers for payments had been carefully examined by the committee, who would submit a full report at the next meeting.

The Secretary explained several features of the appropriations and expenditures of the year, the deposits made with the Corcoran Art Gallery, Army Museum, Department of Agriculture, &c.

A statement of the circumstances attending a theft of $154.50 from the office of the Secretary of the Institution, was made by Prof. Henry, and, on motion of Mr. Sargent, it was

Resolved, That the amount of the loss ($154.50) be charged in the account to "incidental expenses."

The reading of the report of the Secretary was then resumed.

At the suggestion of the Secretary, it was

Resolved, That a committee, consisting of Professors Gray and

Coppée, be appointed to examine and report on the present condition of the *museum*, especially the ethnological department.

The board then adjourned to meet on Saturday evening, January 23, at 7 o'clock.

WASHINGTON, *January* 23, 1875.

A meeting of the Board of Regents was held this day, at 7 o'clock p. m.

Present, the Chancellor, Chief-Justice Waite, Senators H. Hamlin, J. W. Stevenson, and A. A. Sargent; Representatives S. S. Cox, E. R. Hoar, G. W. Hazelton; Hon. Peter Parker, Prof. Asa Gray, Prof. H. Coppée, Hon. George Bancroft, and the Secretary, Professor Henry.

The minutes of the last meeting were approved.

Dr. Parker presented the annual report of the Executive Committee, which was read and, on motion of Mr. Hamlin, adopted.

Dr. Gray, from the special committee to examine the museum, presented the following report, which, on motion of Mr. Sargent, was accepted and ordered to be printed in the proceedings of the board:

REPORT OF SPECIAL COMMITTEE ON THE MUSEUM.

Your committee appointed to examine the museum has devoted as much time to the examination as the members of it could secure during the past two or three days, and would respectfully offer a few remarks upon its condition. It is not supposed that any full or detailed report is expected. We will confine our observations to the ethnological museum, the only one we have found time to inspect with any care.

At the previous session of the board, about nine months ago, the large upper hall had barely been made ready to receive the ethnological and archæological collections, and a portion of the wall-cases only were in place. The progress that has been made in the interval is very gratifying. The hall, although not filled, has been well supplied with glazed cases, for the most part excellent in plan and construction; and the very large and varied collection of objects is arranged in them and displayed to public view. There is still much to be done in perfecting the the arrangement and the labeling, and there are recent accessions to be added. But even now, it is a great pleasure to see how well cared for and how important this museum is, and how much it interests a numerous throng of visitors. In this respect it seems likely to be even more attractive than the museum of natural history underneath. It is only when an ethnological collection is brought together upon a comprehensive scale, and is well arranged upon some intelligible principle, that any one realizes its interest and importance.

The arrangement which is, as we may say, technological rather than geographical, appears to be the one best adapted for such a museum—most useful to the serious student as well as most instructive and curious to the general visitor. Objects of the same class or subservient to the same purpose are brought together from whatever country, and of whatever age. Articles of dress, ornament, or food, implements for their preparation, utensils for domestic use, nets, weapons, and the like thus illustrate each other.

Among the special collections, newly put together, we were much interested in the very full one of the food, especially the vegetable food of the different tribes of the North American Indians; in the collection of their cradles or analogous appliances for the care of infants; in the collection of musical instruments, or what was intended to answer the purpose of music; and in the fine pottery of the Arizonian and other tribes.

The museum is especially rich in stone implements of the North American continent, mainly prehistoric; also in specimens of the survival of the art of working stone weapons of the finest kind, in some of our native tribes.

In the further development of the museum it may be thought best to arrange the archæological specimens in a separate series, but, as to America, it is not easy to draw a line between what is prehistoric, and what belongs essentially to the present era.

A great number of duplicates will soon be ready for exchange. Besides proper duplicates, freely available for exchange, there is, wherever the materials and the subject admit of it, a selected series carefully packed away in the lower part of the cases, or directly underneath the typical specimens or specimens selected for exhibition. For public inspection in very large museums it is now a recognized principle that the half is better than the whole; that typical specimens, those that best exemplify the leading forms or plans, should be exhibited in preference to full series of gradations and modifications. But the serious investigator needs all the forms, and this selected students' series, which is mostly out of sight, is carefully preserved for, and is accessible to, his use.

A great deal of important ethnological matter has of late years been collected in the form of photographs, and it seems obviously important that such collections should be systematically made and preserved, is not on the large scale, yet in the compact and effective form of stereoscopic views. If the figures, the costumes, and the dwellings of our various tribes still remaining are not perpetuated in this way very promptly, much which is now easy to preserve will be irretrievably lost to the future.

In this connection we would suggest that it might be well to provide a series of figures characteristic of the races of men, and especially of the North American races and tribes. This would require considerable room for exhibition and a great deal of judgment as to the mode of getting up the material to be employed, and the extent to which this kind of illustration should be introduced.

This museum is very rapidly increasing, and it is remarkable that the accessions are made almost without pecuniary cost. Hardly any have been purchased. They came from scientific or curious explorers, whom the Smithsonian Institution is everywhere exciting and furthering, and from Government expeditions commissioned mainly for other important objects; and the facilities in the way of transportation controlled by the Institution are such that even the cost of their delivery in Washington is trifling.

It will be interesting to know to what extent the museums which the Smithsonian Institution has in charge are visited by the public. The committee would suggest the use of a recording turnstile at the entrance, by which the number of visitors might be indicated and preserved with very little trouble.

Respectfully submitted.

ASA GRAY.
HENRY COPPÉE.

Doctor Parker, in behalf of the Executive Committee, stated that the heating-apparatus now employed was found insufficient in extremely cold weather to warm the building, particularly the new ethnological hall, and suggested the propriety of asking Congress to appropriate $2,500 to increase the means for heating the building.

Mr. Bancroft remarked that this was not asking anything for the benefit of the Smithsonian Institution, but for the comfort of the people of the United States who come here to see the great collections of the Government, and who should certainly be provided with the means of doing this without the danger of taking cold.

On motion of Mr. Bancroft it was—

Resolved, That Congress be requested to make an appropriation of $2,500 to increase the heating capacity of the apparatus used to warm the rooms occupied by the Government collections.

The reading of the report of the Secretary was then continued.

On motion of Mr. Cox, it was—

Resolved, That the report of the Secretary be accepted and transmitted to Congress as usual.

The board then adjourned *sine die.*

LAPLACE.

EULOGY BY ARAGO BEFORE THE FRENCH ACADEMY.

TRANSLATED BY PROF. BADEN POWELL.

Having been appointed to draw up the report of a committee of the Chamber of Deputies, which was nominated in 1842, for the purpose of taking into consideration the expediency of a proposal submitted to the chamber by the minister of public instruction, relative to the publication of a new edition of the works of Laplace at the public expense, I deemed it to be my duty to embody in the report a concise analysis of the works of our illustrious countryman. Several persons, influenced, perhaps, by too indulgent a feeling toward me, having expressed a wish that this analysis should not remain buried amid a heap of legislative documents, but that it should be published in the Annuaire du Bureau des Longitudes, I took advantage of this circumstance to develop it more fully, so as to render it less unworthy of public attention. The scientific part of the report presented to the Chamber of Deputies will be found here entire. It has been considered desirable to suppress the remainder. I shall merely retain a few sentences containing an explanation of the object of the proposed law, and an announcement of the resolutions which were adopted by the three powers of the state.

Laplace has endowed France, Europe, the scientific world, with three magnificent compositions, the Traité de Mécanique Céleste, the Exposition du Système du Monde, and the Théorie Analytique des Probabilités. In the present day (1842) there is no longer to be found a single copy of this last work at any book-seller's establishment in Paris. The edition of the Mécanique Céleste itself will soon be exhausted. It was painful, then, to reflect that the time was close at hand when persons engaged in the study of the higher mathematics would be compelled, for want of the original work, to inquire at Philadelphia, at New York, or at Boston for the English translation of the *chef d'œvre* of our countryman by the excellent geometer, Bowditch. These fears, let us hasten to state, were not well founded. To republish the Mécanique Céleste was, on the part of the family of the illustrious geometer, to perform a pious duty. Accordingly, Madame de Laplace, who is so justly, so profoundly attentive to every circumstance calculated to enhance the renown of the name which she bears, did not hesitate about pecuniary considerations. A small property near Pont l'Evêque was about to change hands, and the proceeds were to have been applied so that Frenchmen should not be deprived of the satisfaction of exploring the treasures of the Mécanique Céleste through the medium of the vernacular tongue.

"The republication of the complete works of Laplace rested upon an equally sure guarantee. Yielding at once to filial affection, to a noble feeling of patriotism, and to the enthusiasm for brilliant discoveries which a course of severe study inspired, General Laplace had long since qualified himself for becoming the editor of the seven volumes which are destined to immortalize his father.

"There are glorious achievements of a character too elevated, of a luster too splendid, that they should continue to exist as objects of private property. Upon the state devolves the duty of preserving them from indifference and oblivion, of continually holding them up to attention, of diffusing a knowledge of them through a thousand channels; in a word, of rendering them subservient to the public interests.

"Doubtless the minister of public instruction was influenced by these considerations when, upon the occasion of a new edition of the works of Laplace having become necessary, he demanded of you to substitute the great French family for the personal family of the illustrious geometer. We give our full and unreserved adhesion to this proposition. It springs from a feeling of patriotism, which will not be gainsaid by any one in this assembly."

In fact, the Chamber of Deputies had only to examine and solve this single question : "Are the works of Laplace of such transcendent, such exceptional merit that their republication ought to form the subject of deliberation of the great powers of the state? An opinion prevailed that it was not enough merely to appeal to public notoriety, but that it was necessary to give an exact analysis of the brilliant discoveries of Laplace in order to exhibit more fully the importance of the resolution about to be adopted. Who could hereafter propose on any similar occasion that the chamber should declare itself without discussion when a desire was felt, previous to voting in favor of a resolution so honorable to the memory of a great man, to fathom, to measure, to examine minutely and from every point of view monuments such as the Mécanique Céleste and the Exposition du Système du Monde? It has appeared to me that the report drawn up in the name of a committee of one of the three great powers of the state might worthily close this series of biographical notices of eminent astronomers."*

The Marquis de Laplace, peer of France, one of the forty of the French Academy, member of the Academy of Sciences and of the Bureau des Longitudes, an associate of all the great academies or scientific societies of Europe, was born at Beaumonten-Ange, of parents belonging to the class of small farmers, on the 28th day of March, 1749. He died on the 5th of March, 1827.

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* The author here refers to the series of biographies contained in tome III of the Notices Biographiques.—TRANSLATOR.

The first and second volumes of the Mécanique Céleste were published in 1799; the third volume appeared in 1802; the fourth volume in 1805. As regards the fifth volume, books XI and XII were published in 1823; books XIII, XIV, and XV in 1824, and book XVI in 1825. The Théorie des Probabilités was published in 1812. We shall now present the reader with the history of the principal astronomical discoveries contained in these immortal works.

Astronomy is the science of which the human mind may most justly boast. It owes this indisputable pre-eminence to the elevated nature of its object, to the grandeur of its means of investigation, to the certainty, the utility, and the unparalleled magnificence of its results.

From the earliest period of the social existence of mankind, the study of the movements of the heavenly bodies has attracted the attention of governments and peoples. To several great captains, illustrious statesmen, philosophers, and eminent orators of Greece and Rome it formed a subject of delight. Yet, let us be permitted to state, astronomy truly worthy of the name is quite a modern science. It dates only from the sixteenth century. Three great, three brilliant phases have marked its progress. In 1543, Copernicus overthrew, with a firm and bold hand, the greater part of the antique and venerable scaffolding with which the illusions of the senses and the pride of successive generations had filled the universe. The earth ceased to be the center, the pivot of the celestial movements. It henceforward modestly ranged itself among the planets; its material importance, amid the totality of the bodies of which our solar system is composed, found itself reduced almost to that of a grain of sand.

Twenty-eight years had elapsed from the day when the Canon of Thorn expired, while holding in his faltering hands the first copy of the work which was to diffuse so bright and pure a flood of glory upon Poland, when Würtemberg witnessed the birth of a man who was destined to achieve a revolution in science not less fertile in consequences, and still more difficult of execution. This man was Kepler. Endowed with two qualities which seemed incompatible with each other, a volcanic imagination and a pertinacity of intellect which the most tedious numerical calculations could not daunt, Kepler conjectured that the movements of the celestial bodies must be connected together by simple laws, or, to use his own expression, by harmonic laws. These laws he undertook to discover. A thousand fruitless attempts, errors of calculation inseparable from a colossal undertaking, did not prevent him a single instant from advancing resolutely toward the goal of which he imagined he had obtained a glimpse. Twenty-two years were employed by him in this investigation, and still he was not weary of it! What, in reality, are twenty-two years of labor to him who is about to become the legislator of worlds; who shall inscribe his name in ineffaceable characters upon the frontispiece of an immortal code; who shall be able to exclaim in dithyrambic language, and without incurring the reproach of any one, "The die is cast; I have written my book; it will be read either in the present age or by posterity, it matters not which; it may well await a reader, since God has waited six thousand years for an interpreter of his works!"* To investigate a physical cause capable of making the planets revolve in closed curves; to place the principle of the stability of the universe in mechanical forces, and not in solid supports, such as the spheres of crystal which our ancestors had dreamed of; to extend to the revolutions of the heavenly bodies the general principles of the mechanics of terrestrial bodies, such were the questions which remained to be solved after Kepler had announced his discoveries to the world.

Very distinct traces of these great problems are perceived here and there among the ancients as well as the moderns, from Lucretius and Plutarch down to Kepler, Bouillaud, and Borelli. It is to Newton, however, that we must award the merit of their solution. This great man, like several of his predecessors, conceived the celestial bodies to have a tendency to approach toward each other in virtue of an attractive force, deduced the mathematical characteristics of this force from the laws of Kepler, extended it to all the material molecules of the solar system, and developed his brilliant discovery in a work which, even in the present day, is regarded as the most eminent production of the human intellect.

The heart aches when, studying the history of the sciences, we perceive so magnificent an intellectual movement effected without the co-operation of France. Practical astronomy increased our inferiority The means of investigation were at first inconsiderately intrusted to foreigners, to the prejudice of Frenchmen abounding in intelligence and zeal. Subsequently intellects of a superior order struggled with courage, but in vain, against the unskillfulness of our artists. During this period Bradley, more fortunate, on the other side of the Channel, immortalized himself by the discovery of aberration and nutation.

The contribution of France to these admirable revolutions in astronomical science consisted, in 1740, of the experimental determination of the spheroidal figure of the earth, and of the discovery of the variation of gravity upon the surface of our planet. These were two great results; our country, however, had a right to demand more: when France is not in the first rank she has lost her place.[*]

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* These celebrated laws, known in astronomy as the laws of Kepler, are three in number. The first law is, that the planets describe ellipses around the sun in their common focus; the second, that a line joining the planet and the sun sweeps over equal areas in equal times; the third, that the squares of the periodic times of the planets are proportional to the cubes of their mean distances from the sun. The first two laws were discovered by Kepler in the course of a laborious examination of the theory of the planet Mars; a full account of this inquiry is contained in his famous work De Stella Martis, published in 1609. The discovery of the third law was not effected until several years afterward. Kepler announced it to the world in his treatise on Harmonics, (1628.) The passage quoted below is extracted from that work.—TRANSLATOR.

This rank, which was lost for a moment, was brilliantly regained, an achievement for which we are indebted to four geometers. When Newton, giving to his discoveries a generality which the laws of Kepler did not imply, imagined that the different planets were not only attracted by the sun, but that they also attract each other, he introduced into the heavens a cause of universal disturbance. Astronomers could then see at the first glance that in no part of the universe, whether near or distant, would the Keplerian laws suffice for the exact representation of the phenomena; that the simple, regular movements with which the imaginations of the ancients were pleased to endue the heavenly bodies would experience numerous, considerable, perpetually changing perturbations.

To discover several of these perturbations, to assign their nature, and in a few rare cases their numerical values, such was the object which Newton proposed to himself in writing the Principia Mathematica Philosophiæ Naturalis.

Notwithstanding the incomparable sagacity of its author, the Principia contained merely a rough outline of the planetary perturbations. If this sublime sketch did not become a complete portrait, we must not attribute the circumstance to any want of ardor or perseverance; the efforts of the great philosopher were always superhuman; the questions which he did not solve were incapable of solution in his time. When the mathematicians of the Continent entered upon the same career, when they wished to establish the Newtonian system upon an incontrovertible basis, and to improve the tables of astronomy, they actually found in their way difficulties which the genius of Newton had failed to surmount.

Five geometers, Clairaut, Euler, D'Alembert, Lagrange, and Laplace, shared between them the world of which Newton had disclosed the existence. They explored it in all directions, penetrated into regions which had been supposed inaccessible, pointed out there a multitude of phenomena which observation had not yet detected—finally—and it is this which constitutes their imperishable glory—they reduced under the domain of a single principle, a single law, everything that was most refined and mysterious in the celestial movements. Geometry had thus the boldness to dispose of the future. The evolutions of ages are scrupulously ratifying the decisions of science.

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[*] The spheroidal figure of the earth was established by the comparison of an arc of the meridian that had been measured, in France, with a similar arc measured in Lapland, from which it appeared that the length of a degree of the meridian increases from the equator toward the poles, conformably to what ought to result upon the supposition of the earth having the figure of an oblate spheroid. The length of the Lapland arc was determined by means of an expedition which the French government had dispatched to the north of Europe for that purpose. A similar expedition had been dispatched from France about the same time to Peru, in South America, for the purpose of measuring an arc of the meridian under the equator, but the results had not been ascertained at the time to which the author alludes in the text. The variation of gravity at the surface of the earth was established by Richer's experiments with the pendulum at Cayenne, in South America, (1673–'74,) from which it appeared that the pendulum oscillates more slowly, and consequently the force of gravity is less intense, under the equator than in the latitude of Paris.—TRANSLATOR.

We shall not occupy our attention with the magnificent labors of Euler. We shall, on the contrary, present the reader with a rapid analysis of the discoveries of his four rivals, our countrymen.* If a celestial body—the moon, for example—gravitated solely toward the center of the earth, it would describe a mathematical ellipse. It would strictly obey the laws of Kepler, or, which is the same thing, the principles of mechanics expounded by Newton in the first sections of his immortal work.

Let us now consider the action of a second force. Let us take into account the attraction which the sun exercises upon the moon. In other words, instead of two bodies, let us suppose three to operate on each other. The Keplerian ellipse will now furnish merely a rough indication of the motion of our satellite. In some parts the attraction of the sun will tend to enlarge the orbit, and will in reality do so. In other parts, the effect will be the reverse of this. In a word, by the introduction of a third attractive body, the greatest complication will succeed to a simple, regular movement upon which the mind reposed with complacency.

If Newton gave a complete solution of the question of the celestial movements in the case wherein two bodies attract each other, he did not even attempt an analytical investigation of the infinitely more difficult problem of three bodies. The problem of three bodies, (this is the name by which it has become celebrated,) the problem for determining the movement of a body subjected to the attractive influence of two other bodies, was solved for the first time by our countryman Clairaut.† From this solution we may date the important improvements of the lunar tables effected in the last century.

The most beautiful astronomical discovery of antiquity is that of the precession of the equinoxes. Hipparchus, to whom the honor of it is due, gave a complete and precise statement of all the consequences which flow from this movement. Two of these have more especially attracted attention.

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* It may, perhaps, be asked why we place Lagrange among the French geometers. This is our reply: It appears to us that the individual who was named Lagrange Tournier—two of the most characteristic French names which it is possible to imagine—whose maternal grandfather was M. Gros, whose paternal great grandfather was a French officer, a native of Paris, who never wrote except in French, and who was invested in our country with high honors during a period of nearly thirty years, ought to be regarded as a Frenchman, although born at Turin.—AUTHOR.

† The problem of three bodies was solved independently about the same time by Euler, D'Alembert, and Clairaut. The two last-mentioned geometers communicated their solutions to the Academy of Sciences on the same day—November 15, 1747. Euler had already, in 1746, published tables of the moon, founded on his solution of the same problem, the details of which h subsequently published, in 1753.—TRANSLATOR.

By reason of the precession of the equinoxes, it is not always the same groups of stars, the same constellations, which are perceived in the heavens at the same season of the year. In the lapse of ages the constellations of winter will become those of summer, and reciprocally.

By reason of the precession of the equinoxes, the pole does not always occupy the same place in the starry vault. The moderately bright star which is very justly named in the present day the pole star, was far removed from the pole in the time of Hipparchus; in the course of a few centuries it will again appear removed from it. The designation of pole-star has been and will be applied to stars very distant from each other.

When the inquirer, in attempting to explain natural phenomena, has the misfortune to enter upon a wrong path, each precise observation throws him into new complications. Seven spheres of crystal did not suffice for representing the phenomena as soon as the illustrious astronomer of Rhodes discovered precession. An eighth sphere was then wanted to account for a movement in which all the stars participated at the same time.

Copernicus having deprived the earth of its alleged immobility, gave a very simple explanation of the most minute circumstances of precession. He supposed that the axis of rotation does not remain exactly parallel to itself; that in the course of each complete revolution of the earth around the sun the axis deviates from its position by a small quantity; in a word, instead of supposing the circumpolar stars to advance in a certain way toward the pole, he makes the pole advance toward the stars. This hypothesis divested the mechanism of the universe of the greatest complication which the love of theorizing had introduced into it. A new Alphonse would have then wanted a pretext to address to his astronomical synod the profound remark, so erroneously interpreted, which history ascribes to the King of Castile.

If the conception of Copernicus improved by Kepler had, as we have just seen, introduced a striking improvement into the mechanism of the heavens, it still remained to discover the motive force which, by altering the position of the terrestrial axis during each successive year, would cause it to describe an entire circle, of nearly 50° in diameter, in a period of about 26,000 years.

Newton conjectured that this force arose from the action of the sun and moon upon the redundant matter accumulated in the equatorial regions of the earth; thus he made the precession of the equinoxes depend upon the spheroidal figure of the earth; he declared that upon a round planet no precession would exist.

All this was quite true, but Newton did not succeed in establishing it by a mathematical process. Now this great man had introduced into philosophy the severe and just rule: Consider as certain only what has been demonstrated. The demonstration of the Newtonian conception of the precession of the equinoxes was, then, a great discovery, and it is to D'Alembert that the glory of it is due.* The illustrious geometer gave a complete explanation of the general movement in virtue of which the terrestrial axis returns to the same stars in a period of about 26,000 years. He also connected with the theory of gravitation the perturbation of precession discovered by Bradley, that remarkable oscillation which the earth's axis experiences continually during its movement of progression, and the period of which, amounting to about eighteen years, is exactly equal to the time which the intersection of the moon's orbit with the ecliptic employs in describing the 360° of the entire circumference.

Geometers and astronomers are justly occupied as much with the figure and physical constitution which the earth might have had in remote ages as with its present figure and constitution.

As soon as our countryman Richer discovered that a body, whatever be its nature, weighs less when it is transported nearer the equatorial regions, everybody perceived that the earth, if it was originally fluid, ought to bulge out at the equator. Huyghens and Newton did more; they calculated the difference between the greatest and least axes, the excess of the equatorial diameter over the line of the poles.†

The calculation of Huyghens was founded upon hypothetic properties of the attractive force which were wholly inadmissible; that of Newton upon a theorem which he ought to have demonstrated. The theory of the latter was characterized by a defect of a still more serious nature; it supposed the density of the earth, during the original state of fluidity, to be homogeneous.*

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* It must be admitted that M. Arago has here imperfectly represented Newton's labors on the great problem of the precession of the equinoxes. The immortal author of the Principia did not merely conjecture that the conical motion of the earth's axis is due to the disturbing action of the sun and moon upon the matter accumulated around the earth's equator; he demonstrated by a very beautiful and satisfactory process that the movement must necessarily arise from that cause; and although the means of investigation, in his time, were inadequate to a rigorous computation of the quantitative effect, still his researches on the subject have been always regarded as affording one of the most striking proofs of sagacity which is to be found in all his works.—TRANSLATOR.

† It would appear that Hooke had conjectured that the figure of the earth might be spheroidal before Newton or Huyghens turned their attention to the subject. At a meeting of the Royal Society on the 28th of February, 1678, a discussion arose respecting the figure of Mercury, which M. Gallet, of Avignon, had remarked to be oval on the occasion of the planet's transit across the sun's disk on the 7th of November, 1677. Hooke was inclined to suppose that the phenomenon was real, and that it was due to the whirling of the planet on an axis "which made it somewhat of the shape of a turnip, or of a solid made by an ellipsis turned round upon its shorter diameter." At the meeting of the society on the 7th of March, the subject was again discussed. In reply to the objection offered to his hypothesis on the ground of the planet being a solid body, Hooke remarked that "although it might now be solid, yet that at the beginning it might have been fluid enough to receive that shape; and that although this supposition should not be granted, it would be probable enough that it would really run into that shape and make the same appearance; and that it is not improbable but that the water here upon the earth might do it in some measure by the influence of the diurnal motion, which, compounded with that of the moon, he conceived to be the cause of the tides." (Journal Book of the Royal Society, vol. vi, p. 60.) Richer returned from Cayenne

When in attempting the solution of great problems we have recourse to such simplifications; when in order to elude difficulties of calculation we depart so widely from natural and physical conditions, the results relate to an ideal world, they are in reality nothing more than flights of the imagination. In order to apply mathematical analysis usefully to the determination of the figure of the earth, it was necessary to abandon all idea of homogeneity, all constrained resemblance between the forms of the superposed and unequally dense strata; it was necessary also to examine the case of a central solid nucleus. This generality increased tenfold the difficulties of the problem; neither Clairaut nor D'Alembert was, however, arrested by them. Thanks to the efforts of these two eminent geometers, thanks to some essential developments due to their immediate successors, and especially to the illustrious Legendre, the theoretical determination of the figure of the earth has attained all desirable perfection. There now reigns the most satisfactory accordance between the results of calculation and those of direct measurement. The earth, then, was originally fluid; analysis has enabled us to ascend to the earliest ages of our planet.†

In the time of Alexander, comets were supposed by the majority of the Greek philosophers to be merely meteors generated in our atmosphere. During the Middle Ages, persons, without giving themselves much concern about the nature of those bodies, supposed them to prognosti-

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in the year 1674, but the account of his observations with the pendulum during his residence there was not published until 1679, nor is there to be found any allusion to them during the intermediate interval, either in the volumes of the Academy of Sciences or any other publication. We have no means of ascertaining how Newton was first induced to suppose that the figure of the earth is spheroidal, but we know, upon his own authority, that as early as the year 1667 or 1668, he was led to consider the effects of the centrifugal force in diminishing the weight of bodies at the equator. With respect to Huyghens, he appears to have formed a conjecture respecting the spheroidal figure of the earth independently of Newton; but his method for computing the ellipticity is founded upon that given in the Principia.—TRANSLATOR.

* Newton assumed that a homogeneous fluid mass of a spheroidal form would be in equilibrium if it were endued with an adequate rotatory motion and its constituent particles attracted each other in the inverse proportion of the square of the distance. Maclaurin first demonstrated the truth of this theorem by a rigorous application of the ancient geometry.—TRANSLATOR.

† The results of Clairaut's researches on the figure of the earth are mainly embodied in a remarkable theorem discovered by that geometer, and which may be enunciated thus: The sum of the fractions expressing the ellipticity and the increase of gravity at the pole is equal to two and a half times the fraction expressing the centrifugal force at the equator, the unit of force being represented by the force of gravity at the equator. This theorem is independent of any hypothesis with respect to the law of the densities of the successive strata of the earth. Now the increase of gravity at the pole may be ascertained by means of observations with the pendulum in different latitudes. Hence it is plain that Clairaut's theorem furnishes a practical method for determining the value of the earth's ellipticity.—TRANSLATOR.

cate sinister events. Regiomontanus and Tycho Brahé proved by their observations that they are situate beyond the moon; Hevelius, Dörfel, &c., made them revolve around the sun; Newton established that they move under the immediate influence of the attractive force of that body; that they do not describe right lines; that, in fact, they obey the laws of Kepler. It was necessary, then, to prove that the orbits of comets are curves which return into themselves, or that the same comet has been seen on several distinct occasions. This discovery was reserved for Halley; by a minute investigation of the circumstances connected with the apparitions of all the comets to be met with in the records of history, in ancient chronicles, and in astronomical annals, this eminent philosopher was enabled to prove that the comets of 1682, of 1607, and of 1531 were in reality so many successive apparitions of one and the same body.

This identity involved a conclusion before which more than one astronomer shrank. It was necessary to admit that the time of a complete revolution of the comet was subject to a great variation, amounting to as much as two years in seventy-six.

Were such great discordances due to the disturbing action of the planets?

The answer to this question would introduce comets into the category of ordinary planets, or would exclude them forever. The calculation was difficult; Clairaut discovered the means of effecting it. While success was still uncertain, the illustrious geometer gave proof of the greatest boldness, for, in the course of the year 1758, he undertook to determine the time of the following year when the comet of 1682 would re-appear. He designated the constellations, nay, the stars, which it would encounter in its progress.

This was not one of those remote predictions which astrologers and others formerly combined very skillfully with the tables of mortality, so that they might not be falsified during their life-time: the event was close at hand. The question at issue was nothing less than the creation of a new era in cometary astronomy, or the casting of a reproach upon science, the consequences of which it would long continue to feel.

Clairaut found by a long process of calculation, conducted with great skill, that the action of Jupiter and Saturn ought to have retarded the movement of the comet; that the time of revolution, compared with that immediately preceding, would be increased 518 days by the disturbing action of Jupiter, and 100 days by the action of Saturn, forming a total of 618 days, or more than a year and eight months.

Never did a question of astronomy excite a more intense, a more legitimate curiosity. All classes of society awaited with equal interest the announced apparition. A Saxon peasant, Palitzch, first perceived the comet. Henceforward, from one extremity of Europe to the other, a thousand telescopes traced each night the path of the body through the constellations. The route was always, within the limits of precision of the calculations, that which Clairaut had indicated beforehand. The prediction of the illustrious geometer was verified, in regard both to time and space. Astronomy had just achieved a great and important triumph, and, as usual, had destroyed at one blow a disgraceful and inveterate prejudice. As soon as it was established that the returns of comets might be calculated beforehand, those bodies lost forever their ancient prestige. The most timid minds troubled themselves quite as little about them as about eclipses of the sun and moon, which are equally subject to calculation. In fine, the labors of Clairaut had produced a deeper impression on the public mind than the learned, ingenious, and acute reasoning of Bayle. The heavens offer to reflecting minds nothing more curious or more strange than the equality which subsists between the movements of rotation and revolution of our satellite. By reason of this perfect equality the moon always presents the same side to the earth. The hemisphere which we see in the present day is precisely that which our ancestors saw in the most remote ages; it is exactly the hemisphere which future generations will perceive.

The doctrine of final causes which certain philosophers have so abundantly made use of in endeavoring to account for a great number of natural phenomena was in this particular case totally inapplicable. In fact, how could it be pretended that mankind could have any interest in perceiving incessantly the same hemisphere of the moon, in never obtaining a glimpse of the opposite hemisphere? On the other hand, the existence of a perfect, mathematical equality between elements having no necessary connection—such as the movements of translation and rotation of a given celestial body—was not less repugnant to all ideas of probability. There were, besides, two other numerical coincidences quite as extraordinary: an identity of direction, relative to the stars, of the equator and orbit of the moon; exactly the same precessional movements of these two planes. This group of singular phenomena, discovered by J. D. Cassini, constituted the mathematical code of what is called the libration of the moon. The libration of the moon formed a very imperfect part of physical astronomy when Lagrange made it depend on a circumstance connected with the figure of our satellite which was not observable from the earth, and thereby connected it completely with the principles of universal gravitation.

At the time when the moon was converted into a solid body, the action of the earth compelled it to assume a less regular figure than if no attracting body had been situated in its vicinity. The action of our globe rendered elliptical an equator which otherwise would have been circular. This disturbing action did not prevent the lunar equator from bulging out in every direction, but the prominence of the equatorial diameter directed toward the earth became four times greater than that of the diameter which we see perpendicularly.

The moon would appear then, to an observer situate in space and examining it transversely, to be elongated toward the earth, to be a sort of pendulum without a point of suspension. When a pendulum deviates from the vertical, the action of gravity brings it back; when the principal axis of the moon recedes from its usual direction, the earth in like manner compels it to return.

We have here, then, a complete explanation of a singular phenomenon, without the necessity of having recourse to the existence of an almost miraculous equality between two movements of translation and rotation, entirely independent of each other. Mankind will never see but one face of the moon. Observation had informed us of this fact; now we know further that this is due to a physical cause which may be calculated, and which is visible only to the mind's eye; that it is attributable to the elongation which the diameter of the moon experienced when it passed from the liquid to the solid state under the attractive influence of the earth.

If there had existed originally a slight difference between the movements of rotation and revolution of the moon, the attraction of the earth would have reduced these movements to a rigorous equality. This attraction would have even sufficed to cause the disappearance of a slight want of coincidence in the intersections of the equator and orbit of the moon with the plane of the ecliptic.

The memoir in which Lagrange has so successfully connected the laws of libration with the principles of gravitation, is no less remarkable for intrinsic excellence than style of execution. After having perused this production, the reader will have no difficulty in admitting that the word "elegance" may be appropriately applied to mathematical researches.

In this analysis we have merely glanced at the astronomical discoveries of Clairaut, D'Alembert, and Lagrange. We shall be somewhat less concise in noticing the labors of Laplace.

After having enumerated the various forces which must result from the mutual action of the planets and satellites of our system, even the great Newton did not venture to investigate the general nature of the effects produced by them. In the midst of the labyrinth formed by increases and diminutions of velocity, variations in the forms of the orbits, changes of distances and inclinations, which these forces must evidently produce, the most learned geometer would fail to discover a trustworthy guide. This extreme complication gave birth to a discouraging reflection. Forces so numerous, so variable in position, so different in intensity, seemed to be incapable of maintaining a condition of equilibrium except by a sort of miracle. Newton even went so far as to suppose that the planetary system did not contain within itself the elements of indefinite stability; he was of opinion that a powerful hand must intervene from time to time to repair the derangements occasioned by the mutual action of the various bodies. Euler, although farther advanced than Newton in a knowledge of the planetary perturbations, refused also to admit that the solar system was constituted so as to endure forever. Never did a greater philosophical question offer itself to the inquiries of mankind. Laplace attacked it with boldness, perseverance, and success. The profound and long-continued researches of the illustrious geometer established with complete evidence that the planetary ellipses are perpetually variable ; that the extremities of their major axes make the tour of the heavens; that, independently of an oscillatory motion, the planes of their orbits experience a displacement in virtue of which their intersections with the plane of the terrestrial orbit are each year directed toward different stars. In the midst of this apparent chaos there is one element which remains constant, or is merely subject to small periodic changes, namely, the major axis of each orbit, and consequently the time of revolution of each planet. This is the element which ought to have chiefly varied according to the learned speculations of Newton and Euler.

The principle of universal gravitation suffices for preserving the stability of the solar system. It maintains the forms and inclinations of the orbits in a mean condition which is subject to slight oscillations; variety does not entail disorder; the universe offers the example of harmonious relations, of a state of perfection which Newton himself doubted. This depends on circumstances which calculation disclosed to Laplace, and which, upon a superficial view of the subject, would not seem to be capable of exercising so great an influence. Instead of planets revolving all in the same direction, in slightly eccentric orbits, and in planes inclined at small angles toward each other, substitute different conditions, and the stability of the universe will again be put in jeopardy, and, according to all probability, there will result a frightful chaos.*

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* The researches on the secular variations of the eccentricities and inclinations of the planetary orbits depend upon the solution of an algebraic equation equal in degree to the number of planets whose mutual action is considered, and the co-efficients of which involve the values of the masses of those bodies. It may be shown that if the roots of this equation be equal or imaginary, the corresponding element, whether the eccentricity or the inclination, will increase indefinitely with the time in the case of each planet; but that if the roots, on the other hand, be real and unequal, the value of the element will oscillate in every instance within fixed limits. Laplace proved by a general analysis that the roots of the equation are real and unequal; whence it followed that neither the eccentricity nor the inclination will vary in any case to an indefinite extent. But it still remained uncertain whether the limits of oscillation were not in any instance so far apart that the variation of the element (whether the eccentricity or the inclination) might lead to a complete destruction of the existing physical condition of the planet. Laplace, indeed, attempted to prove, by means of two well-known theorems relative to the eccentricities and inclinations of the planetary orbits, that if those elements were once small they would always remain so, provided the planets all revolved around the sun in one common direction, and their masses were inconsiderable. It is to these theorems that M. Arago manifestly alludes in the text. Le Verrier and others have, however, remarked that they are inadequate to assure the permanence of the existing physical condition of several of the planets. In order to arrive at a definite conclusion on this subject, it is indispensable to have recourse to the actual solution of the algebraic question above referred to. This was the course adopted by the illustrious Lagrange in his researches on the secular variations of the planetary orbits. (Mem. Acad. Berlin, 1783–'84.) Having investigated the values of the masses of the planets, he then determined, by an approximate solution, the values of the several roots of the algebraic equation upon which the variations of the eccentricities and inclinations of the orbits de-

Although the invariability of the mean distances of the planetary orbits has been more completely demonstrated since the appearance of the memoir above referred to, that is to say, by pushing the analytical approximations to a greater extent, it will, notwithstanding, always constitute one of the admirable discoveries of the author of the Mécanique Céleste. Dates, in the case of such subjects, are no luxury of erudition. The memoir in which Laplace communicated his results on the invariability of the mean motions or mean distances is dated 1773.* It was in 1784 only that he established the stability of the other elements of the system from the smallness of the planetary masses, the inconsiderable eccentricity of the orbits, and the revolution of the planets in one common direction around the sun.

The discovery of which I have just given an account to the reader excluded, at least from the solar system, the idea of the Newtonian attraction being a cause of disorder; but might not other forces, by combining with attraction, produce gradually-increasing perturbations, as Newton and Euler dreaded? Facts of a positive nature seemed to justify these fears.

A comparison of ancient with modern observations revealed the existence of a continued acceleration of the mean motions of the moon and the planet Jupiter, and an equally striking diminution of the mean motion of Saturn. These variations led to conclusions of the most singular nature.

In accordance with the presumed cause of these perturbations, to say that the velocity of a body increased from century to century, was equivalent to asserting that the body continually approached the center of motion. On the other hand, when the velocity diminished the body must be receding from the center.

Thus, by a strange arrangement of nature, our planetary system seemed destined to lose Saturn, its most mysterious ornament, to see the planet, accompanied by its ring and seven satellites, plunge gradually

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pended. In this way he found the limiting values of the eccentricity and inclination for the orbit of each of the principal planets of the system. The results obtained by that great geometer have been mainly confirmed by the recent researches of Le Verrier on the same subject. (Connaissance des Temps, 1843.)—TRANSLATOR.

* Laplace was originally led to consider the subject of the perturbations of the mean motions of the planets by his researches on the theory of Jupiter and Saturn. Having computed the numerical value of the secular inequality affecting the mean motion of each of those plants, neglecting the terms of the fourth and higher orders relative to the eccentricities and inclinations, he found it to be so small that it might be regarded as totally insensible. Justly suspecting that this circumstance was not attributable to the particular values of the elements of Jupiter and Saturn, he investigated the expression for the secular perturbation of the mean motion by a general analysis, neglecting, as before, the fourth and higher powers of the eccentricities and inclinations, and he found in this case that the terms which were retained in the investigation absolutely destroyed each other, so that the expression was reduced to zero. In a memoir which he communicated to the Berlin Academy of Sciences, in 1776, Lagrange first showed that the mean distance (and consequently the mean motion) was not affected by any secular inequalities, no matter what were the eccentricities or inclinations of the disturbing and disturbed planets.—TRANSLATOR.

into unknown regions, whither the eye, armed with the most powerful telescope, has never penetrated. Jupiter, on the other hand, the planet compared with which the earth is so insignificant, appeared to be moving in the opposite direction, so as to be ultimately absorbed in the incandescent matter of the sun. Finally, the moon seemed as if it would one day precipitate itself upon the earth.

There was nothing doubtful or speculative in these sinister forebodings. The precise dates of the approaching catastrophes were alone uncertain. It was known, however, that they were very distant. Accordingly, neither the learned dissertations of men of science nor the animated descriptions of certain poets produced any impression upon the public mind.

It was not so with our scientific societies, the members of which regarded with regret the approaching destruction of our planetary system. The Academy of Sciences called the attention of geometers of all countries to these menacing perturbations. Euler and Lagrange descended into the arena. Never did their mathematical genius shine with a brighter luster. Still the question remained undecided. The inutility of such efforts seemed to suggest only a feeling of resignation on the subject, when from two disdained corners of the theories of analysis the author of the Mécanique Céleste caused the laws of these great phenomena clearly to emerge. The variations of velocity of Jupiter, Saturn, and the moon flowed, then, from evident physical causes, and entered into the category of ordinary periodic perturbations, depending upon the principle of attraction.

The variations in the dimensions of the orbits, which were so much dreaded, resolved themselves into simple oscillations, included within narrow limits. Finally, by the powerful instrumentality of mathematical analysis, the physical universe was again established on a firm foundation.

I cannot quit this subject without at least alluding to the circumstances in the solar system upon which depend the so long unexplained variations of velocity of the moon, Jupiter, and Saturn.

The motion of the earth around the sun is mainly effected in an ellipse, the form of which is liable to vary from the effects of planetary perturbation. These alterations of form are periodic; sometimes the curve, without ceasing to be elliptic, approaches the form of a circle, while at other times it deviates more and more from that form. From the epoch of the earliest recorded observations, the eccentricity of the terrestrial orbit has been diminishing from year to year; at some future epoch the orbit, on the contrary, will begin to deviate from the form of a circle, and the eccentricity will increase to the same extent as it previously diminished, and according to the same laws.

Now Laplace has shown that the mean motion of the moon around the earth is connected with the form of the ellipse which the earth describes around the sun; that a diminution of the eccentricity of the ellipse inevitably induces an increase in the velocity of our satellite, and *vice versa;* finally, that this cause suffices to explain the numerical value of the acceleration which the mean motion of the moon has experienced from the earliest ages down to the present time.*

The origin of the inequalities in the mean motions of Jupiter and Saturn will be, I hope, as easy to conceive.

Mathematical analysis has not served to represent in finite terms the values of the derangements which each planet experiences in its movement from the action of all the other planets. In the present state of science, this value is exhibited in the form of an indefinite series of terms diminishing rapidly in magnitude. In calculation it is usual to neglect such of those terms as correspond in the order of magnitude to quantities beneath the errors of observation. But there are cases in which the order of the term in the series does not decide whether it be small or great. Certain numerical relations between the primitive elements of the disturbing and disturbed planets may impart sensible values to terms which usually admit of being neglected. This case occurs in the perturbations of Saturn produced by Jupiter, and in those of Jupiter produced by Saturn. There exists between the mean motions of these two great planets a simple relation of commensurability, five times the mean motion of Saturn being, in fact, very nearly equal to twice the mean motion of Jupiter. It happens in consequence that certain terms, which would otherwise be very small, acquire from this circumstance considerable values. Hence arise, in the movements of these two planets, inequalities of long duration, which require more than 900 years for their complete development, and which represent with marvelous accuracy all the irregularities disclosed by observation. Is it not astonishing to find in the commensurability of the mean motions of two planets a cause of perturbation of so influential a nature; to discover that the definitive solution of an immense difficulty, which baffled the genius of Euler, and which even led persons to doubt whether the theory of gravitation was capable of accounting for all the phenomena of the heavens, should depend upon the fortuitous circumstance of five times the mean motion of Saturn being equal to twice the mean motion of Jupiter? The beauty of the conception and the ultimate result are here equally worthy of admiration.*

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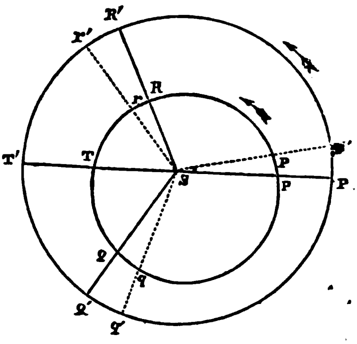
* Mr. Adams has recently detected a remarkable oversight committed by Laplace and his successors in the analytical investigation of the expression for this inequality. The effect of the rectification rendered necessary by the researches of Mr. Adams will be to diminish by about one-sixth the co-efficient of the principal term of the secular inequality. This co-efficient has for its multiplier the square of the number of centuries which have elapsed from a given epoch; its value was found by Laplace to be 10″.18. Mr. Adams has ascertained that it must be diminished by 1″.66. This result has recently been verified by the researches of M. Plana. Its effect will be to alter in some degree the calculations of ancient eclipses. The astronomer royal has stated, in his last annual report to the board of visitors of the Royal Observatory, (June, 1856,) that steps have recently been taken at the observatory for calculating the various circumstances of those phenomena, upon the basis of the more correct data furnished by the researches of Mr. Adams.—TRANSLATOR.



* The origin of this famous inequality may be best understood by reference to the mode in which the disturbing forces operate. Let P Q R, P' Q' R' represent the orbits of Jupiter and Saturn and let us suppose, for the sake of illustration, that they are both situate in the same plane. Let the planets be in conjunction at P, P', and let them both be revolving around the sun S, in the direction represented by the arrows. Assuming that the mean motion of Jupiter is to that of Saturn exactly in the proportion of five to two, it follows that when Jupiter has completed one revolution, Saturn will have advanced through two-fifths of a revolution. Similarly, when Jupiter has completed a revolution and a half, Saturn will have effected three-fifths of a revolution. Hence, when Jupiter arrives at T, Saturn will be a little in advance of T'. Let us suppose that the two planets come again into conjunction at Q, Q'. It is plain that while Jupiter has completed one revolution, and advanced through the angle P S Q, (measured in the direction of the arrow,) Saturn has simply described around S the angle P' S' Q'. Hence the excess of the angle described around S, by Jupiter, over the angle similarly described by Saturn, will amount to one complete revolution, or 360°. But since the mean motions of the two planets are in the proportion of five to two, the angles described by them around S in any given time will be in the same proportion, and therefore the excess of the angle described by Jupiter over that described by Saturn will be to the angle described by Saturn in the proportion of three to two. But we have just found that the excess of these two angles in the present case amounts to 360°, and the angle described by Saturn is represented by P' S' Q'; consequently 360° is to the angle P' S' Q' in the proportion of three to two; in other words, P' S' Q' is equal to two-thirds of the circumference, or 240°. In the same way it may be shown that the two planets will come into conjunction again at R, when Saturn has described another arc of 240°. Finally, when Saturn has advanced through a third arc of 240°, the two planets will come into conjunction at P, P', the points whence they originally set out; and the two succeeding conjunctions will also manifestly occur at Q, Q' and R, R'. Thus we see that the conjunctions will always occur in three given points of the orbit of each planet situate at angular distances of 120° from each other. It is also obvious that, during the interval which elapses between the occurrence of two conjunctions in the same points of the orbits, and which includes three synodic revolutions of the planets, Jupiter will have accomplished five revolutions around the sun, and Saturn will have accomplished two revolutions. Now, if the orbits of both planets were perfectly circular, the retarding and accelerating effects of the disturbing force of either planet would neutralize each other in the course of a synodic revolution, and therefore both planets would return to the same condition at each successive conjunction. But in consequence of the ellipticity of the orbits, the retarding effect of the disturbing force is manifestly no longer exactly compensated by the accelerative effect, and hence, at the close of each synodic revolution, there remains a minute outstanding alteration in the movement of each planet. A similar effect will be produced at each of the three points of conjunction, and as the perturbations which thus ensue do not generally compensate each other, there will remain a minute outstanding perturbation as the result of every three conjunctions. The effect produced being of the same kind (whether tending to accelerate or retard the movement of the planet) for every such triple conjunction, it is plain that the action of the disturbing forces would ultimately lead to a serious derangement of the movements of both planets. All this is founded on the supposition that the mean motions of the two planets are to each other as two to five, but in reality this relation does not exactly hold. In fact while Jupiter requires 21,663 days to accomplish five revolutions, Saturn effects two revolutions in 21,518 days. Hence when Jupiter after completing his fifth revolution arrives at P, Saturn will have advanced a little beyond P', and the con-

We have just explained how Laplace demonstrated that the solar system can experience only small periodic oscillations around a certain mean state. Let us now see in what way he succeeded in determining the absolute dimensions of the orbits.

What is the distance of the sun from the earth? No scientific question has occupied, in a greater degree, the attention of mankind; mathematically speaking, nothing is more simple. It suffices, as in common operations of surveying, to draw visual lines from the two extremities of a known base to an inaccessible object. The remainder is a process of elementary calculation. Unfortunately, in the case of the sun, the distance is great, and the bases which can be measured upon the earth are comparatively very small. In such a case the slightest errors in the direction of the visual lines exercise an enormous influence upon the results.

In the beginning of the last century, Halley remarked that certain interpositions of Venus between the earth and the sun, or, to use an expression applied to such conjunctions, that the transits of the planet across the sun's disk, would furnish at each observatory an indirect means of fixing the position of the visual ray very superior in accuracy to the most perfect direct methods.*

Such was the object of the scientific expeditions undertaken in 1761

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junction of the two planets will occur at P, P′ when they have both described around S an additional arc of about 8°. In the same way it may be shown that the two succeeding conjunctions will take place at the points *q*, *q′ r*, *r′* respectively 8° in advance of Q, Q′, R, R′. Thus we see that the points of conjunction will travel with extreme slowness in the same direction as that in which the planets revolve. Now, since the angular distance between P and R is 120°, and since in a period of three synodic revolutions, or 21,758 days, the line of conjunction travels through an arc of 8°, it follows that in 892 years the conjunction of the two planets will have advanced from P, P′ to R, R′. In reality the time of traveling from P, P′ to R, R′ is somewhat longer from the indirect effects of planetary perturbation, amounting to 920 years. In an equal period of time, the conjunction of the two planets will advance from Q, Q′ to R, R′ and from R, R′ to P, P′. During the half of this period the perturbative effect resulting from every triple conjunction will lie constantly in one direction, and during the other half it will lie in the contrary direction; that is to say, during a period of 460 years, the mean motion of the disturbed planet will be continually accelerated, and, in like manner, during an equal period it will be continually retarded. In the case of Jupiter disturbed by Saturn, the inequality in longitude amounts at its maximum to 21′; in the converse case of Saturn disturbed by Jupiter, the inequality is more considerable in consequence of the greater mass of the disturbing planet, amounting at its maximum to 49′. In accordance with the mechanical principle of the equality of action and reaction, it happens that while the mean motion of one planet is increasing, that of the other is diminishing, and *vice versa*. We have supposed that the orbits of both planets are situate in the same plane. In reality, however, they are inclined to each other, and this circumstance will produce an effect exactly analogous to that depending on the eccentricities of the orbits. It is plain that the more nearly the mean motions of the two planets approach a relation of commensurability, the smaller will be the displacement of every third conjunction, and consequently the longer will be the duration, and the greater the ultimate accumulation, of the inequality.—TRANSLATOR.

* The utility of observations of the transits of the inferior planets for determining the solar parallax was first pointed out by James Gregory. (Optica Promota, 1663.)—TRANSLATOR.

and 1769, on which occasions France—not to speak of stations in Europe—was represented at the isle of Rodrigo by Pingré; at the isle of San Domingo by Fleurin; at California by the Abbé Chappe; at Pondicherry by Legentil. At the same epochs England sent Maskelyne to St. Helena; Wales to Hudson's Bay; Mason to the Cape of Good Hope; Captain Cooke to Otaheite, &c. The observations of the southern hemisphere, compared with those of Europe, and especially with the observations made by an Austrian astronomer, Father Hell, at Wardhus, in Lapland, gave, for the distance of the sun, the result which has since figured in all treatises on astronomy and navigation.

No government hesitated in furnishing academies with the means, however expensive they might be, of conveniently establishing their observers in the most distant regions. We have already remarked that the determination of the contemplated distance appeared to demand imperiously an extensive base; for small bases would have been totally inadequate to the purpose. Well, Laplace has solved the problem numerically, without a base of any kind whatever. He has deduced the distance of the sun from observations of the moon made in one and the same place!

The sun is, with respect to our satellite, the cause of perturbations which evidently depend on the distance of the immense luminous globe from the earth. Who does not see that these perturbations would diminish if the distance increased; that they would increase, on the contrary, if the distance diminished; that the distance finally determines the magnitude of the perturbations?

Observation assigns the numerical value of these perturbations; theory, on the other hand, unfolds the general mathematical relation, which connects them with the solar parallax, and with other known elements. The determination of the mean radius of the terrestrial orbit then becomes one of the most simple operations of algebra. Such is the happy combination by the aid of which Laplace has solved the great, the celebrated problem of parallax. It is thus that the illustrious geometer found for the mean distance of the sun from the earth, expressed in radii of the terrestrial orbit, a value differing only in a slight degree from that which was the fruit of so many troublesome and expensive voyages. According to the opinion of very competent judges, the result of the indirect method might not impossibly merit the preference.*

The movements of the moon proved a fertile mine of research to our great geometer. His penetrating intellect discovered in them unknown treasures. He disentangled them from everything which concealed them from vulgar eyes with an ability and a perseverance equally worthy of admiration. The reader will excuse me for citing another of such examples.

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*Mayer, from the principles of gravitation, (Theoria Lunæ, 1767,) computed the value of the solar parallax to be 7″.8. He remarked that the error of this determination did not amount to one-twentieth of the whole, whence it followed that the true value of the parallax could not exceed 8″.2. Laplace, by an analogous process, determined the parallax to be 8″.45. Encke, by a profound discussion of the observations of the transits of Venus in 1761 and 1769, found the value of the same element to be 8″.5776.—TRANSLATOR.

The earth governs the movements of the moon. The earth is flattened; in other words, its figure is spheroidal. A spheroidal body does not attract like a sphere. There ought, then, to exist in the movement, I had almost said in the countenance, of the moon a sort of impression of the spheroidal figure of the earth. Such was the idea as it originally occurred to Laplace.

It still remained to ascertain (and here consisted the chief difficulty) whether the effects attributable to the spheroidal figure of the earth were sufficiently sensible not to be confounded with the errors of observation. It was accordingly necessary to find the general formula of perturbations of this nature, in order to be able, as in the case of the solar parallax, to eliminate the unknown quantity.

The ardor of Laplace, combined with his power of analytical research, surmounted all obstacles. By means of an investigation which demanded the most minute attention, the great geometer discovered in the theory of the moon's movements two well-defined perturbations depending on the spheroidal figure of the earth. The first affected the resolved element of the motion of our satellite, which is chiefly measured with the instrument known in observatories by the name of the transit instrument; the second, which operated in the direction north and south, could only be effected by observations with a second instrument, termed the mural circle. These two inequalities, of very different magnitudes, connected with the cause which produces them, by analytical combinations of totally different kinds, have, however, both conducted to the same value of the ellipticity. It must be borne in mind, however, that the ellipticity, thus deduced from the movements of the moon, is not the ellipticity corresponding to such or such a country, the ellipticity observed in France, in England, in Italy, in Lapland, in North America, in India, or in the region of the Cape of Good Hope, for the earth's materials having undergone considerable upheavings at different times, and in different places, the primitive regularity of its curvature has been sensibly disturbed by this cause. The moon—and it is this circumstance which renders the result of such inestimable value—ought to assign, and has in reality assigned, the general ellipticity of the earth; in other words, it has indicated a sort of mean value of the various determinations obtained at enormous expense, and with infinite labor, as the result of long voyages undertaken by astronomers of all the countries of Europe.

I shall add a few brief remarks, for which I am mainly indebted to the author of the Mécanique Céleste. They seem to be eminently adapted for illustrating the profound, the unexpected, and almost paradoxical character of the methods which I have just attempted to sketch.

What are the elements which it has been found necessary to confront with each other in order to arrive at results expressed even to the precision of the smallest decimals?

On the one hand, mathematical formulæ deduced from the principle of universal attraction; on the other hand, certain irregularities observed in the returns of the moon to the meridian.

An observing geometer who, from his infancy, had never quitted his chamber of study, and who had never viewed the heavens except through a narrow aperture directed north and south, in the vertical plane of which the principal astronomical instruments are made to move—to whom nothing had ever been revealed respecting the bodies revolving above his head, except that they attract each other according to the Newtonian law of gravitation—would, however, be enabled to ascertain that his narrow abode was situated upon the surface of a spheroidal body, the equatorial axis of which surpassed the polar axis by a three hundred and sixth part; he would have also found, in his isolated, immovable position, his true distance from the sun.

I have stated at the commencement of this notice that it is to D'Alembert we owe the first satisfactory mathematical explanation of the phenomenon of the precession of the equinoxes. But our illustrious countryman, as well as Euler, whose solution appeared subsequently to that of D'Alembert, omitted all consideration of certain physical circumstances, which, however, did not seem to be of a nature to be neglected without examination. Laplace has supplied this deficiency. He has shown that the sea, notwithstanding its fluidity, and that the atmosphere, notwithstanding its currents, exercise the same influence on the movements of the terrestrial axis as if they formed solid masses adhering to the terrestrial spheroid.

Do the extremities of the axis around which the earth performs an entire revolution once in every twenty-four hours correspond always to the same material points of the terrestrial spheroid? In other words, do the poles of rotation, which from year to year correspond to different stars, undergo also a displacement at the surface of the earth?

In the case of the affirmative, the equator is movable as well as the poles; the terrestrial latitudes are variable; no country during the lapse of ages will enjoy, even on an average, a constant climate; regions the most different will, in their turn, become circumpolar. Adopt the contrary supposition, and everything assumes the character of an admirable permanence.

The question which I have just suggested, one of the most important in astronomy, cannot be solved by the aid of mere observation, on account of the uncertainty of the early determinations of terrestrial latitude. Laplace has supplied this defect by analysis. The great geometer has demonstrated that no circumstance depending on universal gravitation can sensibly displace the poles of the earth's axis relatively to the surface of the terrestrial spheroid. The sea, far from being an obstacle to the invariable rotation of the earth upon its axis, would, on the contrary, reduce the axis to a permanent condition in consequence of the mobility of the waters and the resistance which their oscillations experience.

The remarks which I have just made with respect to the position of the terrestrial axis are equally applicable to the time of the earth's rotation, which is the unit, the true standard of time. The importance of this element induced Laplace to examine whether its numerical value might not be liable to vary from internal causes, such as earthquakes and volcanoes. It is hardly necessary for me to state that the result obtained was negative.

The admirable memoir of Lagrange upon the libration of the moon seemed to have exhausted the subject. This, however, was not the case.

The motion of revolution of our satellite around the earth is subject to perturbations, technically termed secular, which were either unknown to Lagrange or which he neglected. These inequalities eventually place the body, not to speak of entire circumferences, at angular distances of a semicircle, a circle and a half, &c., from the position which it would otherwise occupy. If the movement of rotation did not participate in such perturbations, the moon in the lapse of ages would present in succession all the parts of its surface to the earth.

This event will not occur. The hemisphere of the moon which is actually invisible will remain invisible forever. Laplace, in fact, has shown that the attraction of the earth introduces into the rotatory motion of the lunar spheroid the secular inequalities which exist in the movement of revolution.

Researches of this nature exhibit in full relief the power of mathematical analysis. It would have been very difficult to have discovered by synthesis truths so profoundly enveloped in the complex action of a multitude of forces.

We should be inexcusable if we omitted to notice the high importance of the labors of Laplace on the improvement of the lunar tables. The immediate object of this improvement was, in effect, the promotion of maritime intercourse between distant countries; and, what was indeed far superior to all considerations of mercantile interest, the preservation of the lives of mariners.

Thanks to a sagacity without parallel, to a perseverance which knew no limits, to an ardor always youthful, and which communicated itself to able co-adjutors, Laplace solved the celebrated problem of the longitude more completely than could have been hoped for in a scientific point of view, with greater precision than the art of navigation, in its utmost refinement, demanded. The ship, the sport of the winds and tempests, has no occasion, in the present day, to be afraid of losing itself in the immensity of the ocean. An intelligent glance at the starry vault indicates to the pilot, in every place and at every time, his distance from the meridian of Paris. The extreme perfection of the existing tables of the moon entitles Laplace to be ranked among the benefactors of humanity.*

In the beginning of the year 1611, Galileo supposed that he found in the eclipses of Jupiter's satellites a simple and rigorous solution of the famous problem of the longitude, and active negotiations were immediately commenced with the view of introducing the new method on board the numerous vessels of Spain and Holland. These negotiations failed. From the discussion, it plainly appeared that the accurate observation of the eclipses of the satellites would require powerful telescopes; but such telescopes could not be employed on board a ship tossed about by the waves.

The method of Galileo seemed, at any rate, to retain all its advantages when applied on land, and to promise immense improvements to geography. These expectations were found to be premature. The movements of the satellites of Jupiter are not by any means so simple as the immortal inventor of the method of longitudes supposed them to be. It was necessary that three generations of astronomers and mathematicians should labor with perseverance in unfolding their most considerable perturbations. It was necessary, in fine, that the tables of those bodies should acquire all desirable and necessary precision, that Laplace should introduce into the midst of them the torch of mathematical analysis.

In the present day, the nautical ephemerides contain, several years in advance, the indication of the times of the eclipses and re-appearances of Jupiter's satellites. Calculation does not yield in precision to direct observation. In this group of satellites, considered as an independent system of bodies, Laplace found a series of perturbations analogous to those which the planets experience. The rapidity of the revolutions unfolds, in a sufficiently short space of time, changes in this system which require centuries for their complete development in the solar system.

Although the satellites exhibit hardly an appreciable diameter even when viewed in the best telescopes, our illustrious countryman was enabled to determine their masses. Finally, he discovered certain simple relations of an extremely remarkable character between the movements of those bodies, which have been called the *laws of Laplace*. Posterity will not obliterate this designation; it will acknowledge the propriety of inscribing in the heavens the name of so great an astronomer beside that of Kepler.

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* The theoretical researches of Laplace formed the basis of Burckhardt's Lunar Tables, which are chiefly employed in computing the places of the moon for the Nautical Almanac and other ephemerides. These tables were defaced by an empiric equation, suggested for the purpose of representing an inequality of long period which seemed to affect the mean longitude of the moon. No satisfactory explanation of the origin of this inequality could be discovered by any geometer, although it formed the subject of much toilsome investigation throughout the present century, until at length M. Hanson found it to arise from a combination of two inequalities due to the disturbing action of Venus. The period of one of these inequalities is 273 years, and that of the other is 239 years. The maximum value of the former is 27″.4, and that of the latter is 23″.2.—TRANSLATOR.

Let us cite two or three of the laws of Laplace:

If we add to the mean longitude of the first satellite twice that of the third, and subtract from the sum three times the mean longitude of the second, the result will be exactly equal to 180°. Would it not be very extraordinary if the three satellites had been placed originally at the distances from Jupiter, and in the positions, with respect to each other, adapted for constantly and rigorously maintaining the foregoing relation? Laplace has replied to this question by showing that it is not necessary that this relation should have been rigorously true at the origin. The mutual action of the satellites would necessarily have reduced it to its present mathematical condition, if once the distances and the positions satisfied the law approximately.

This first law is equally true when we employ the synodical elements. It hence plainly results that the three first satellites of Jupiter can never be all eclipsed at the same time. Bearing this in mind, we shall have no difficulty in apprehending the import of a celebrated observation of recent times, during which certain astronomers perceived the planet for a short time without any of his four satellites. This would not by any means authorize us in supposing the satellites to be eclipsed. A satellite disappears when it is projected upon the central part of the luminous disk of Jupiter, and also when it passes behind the opaque body of the planet.

The following is another very simple law to which the mean motions of the same satellites of Jupiter are subject:

If we add to the mean motion of the first satellite twice the mean motion of the third, the sum is exactly equal to three times the mean motion of the second.*

This numerical co-incidence, which is perfectly accurate, would be one of the most mysterious phenomena in the system of the universe if

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* This law is necessarily included in the law already enunciated by the author relative to the mean longitudes. The following is the most usual mode of expressing these curious relations: 1st, the mean motion of the first satellite, plus twice the mean motion of the third, minus three times the mean motion of the second, is rigorously equal to zero; 2d, the mean longitude of the first satellite, plus twice the mean longitude of the third, minus three times the mean longitude of the second, is equal to 180°. It is plain that if we only consider the mean longitude here to refer to a *given epoch*, the combination of the two laws will assure the existence of an analogous relation between the mean longitudes *for any instant of time whatever*, whether past or future. Laplace has shown, as the author has stated in the text, that if these relations had only been approximately true at the origin, the mutual attraction of the three satellites would have ultimately rendered them rigorously so; under such circumstances the mean longitude of the first satellite, plus twice the mean longitude of the third, minus three times the mean longitude of the second, would continually oscillate about 180° as a mean value. The three satellites would participate in this libratory movement, the extent of oscillation depending in each case on the mass of the satellite and its distance from the primary, but the period of libration is the same for all the satellites, amounting to 2,270 days 18 hours, or rather more than six years. Observations of the eclipses of the satellites have not afforded any indications of the actual existence of such a libratory motion, so that the relations between the mean motions and mean longitudes may be presumed to be always rigorously true.—TRANSLATOR.

Laplace had not proved that the law need only have been approximate at the origin, and that the mutual action of the satellites has sufficed to render it rigorous.

The illustrious geometer who always pursued his researches to their most remote ramifications arrived at the following result: The action of Jupiter regulates the movements of rotation of the satellites, so that, without taking into account the secular perturbations, the time of rotation of the first satellite, plus twice the time of rotation of the third, forms a sum which is constantly equal to three times the time of rotation of the second. Influenced by a deference, a modesty, a timidity, without any plausible motive, our artists in the last century surrendered to the English the exclusive privilege of constructing instruments of astronomy. Thus, let us frankly acknowledge the fact, at the time when Herschel was prosecuting his beautiful observations on the other side of the Channel, there existed in France no instruments adapted for developing them; we had not even the means of verifying them. Fortunately for the scientific honor of our country, mathematical analysis is also a powerful instrument. Laplace gave ample proof of this on a memorable occasion when, from the retirement of his chamber, he predicted, he minutely announced, what the excellent astronomer of Windsor would see with the largest telescopes which were ever constructed by the hand of man.

When Galileo, in the beginning of the year 1610, directed toward Saturn a telescope of very low power, which he had just executed with his own hands, he perceived that the planet was not an ordinary globe, without, however, being able to ascertain its real form. The expression "*tri-corporate*," by which the illustrious Florentine designated the appearance of the planet, implied even a totally erroneous idea of its structure. Our countryman Roberval entertained much sounder views on the subject, but from not having instituted a detailed comparison between his hypothesis and the results of observation, he abandoned to Huyghens the honor of being regarded as the author of the true theory of the phenomena presented by the wonderful planet. Every person knows in the present day that Saturn consists of a globe about 900 times greater than the earth, and a ring. This ring does not touch the ball of the planet, being everywhere removed from it at a distance of 20,000 (English) miles. Observation indicates the breadth of the ring to be 54,000 miles. The thickness certainly does not exceed 250 miles. With the exception of a black streak, which divides the ring throughout its whole contour into two parts of unequal breadth and of different brightness, this strange, colossal bridge without piles had never offered to the most experienced or skillful observer either spot or protuberance adapted for deciding whether it was immovable or endued with a movement of rotation.

Laplace considered it to be very improbable, if the ring was immovable, that its constituent parts should be capable of resisting by their mere cohesion the continual attraction of the planet. A movement of rotation occurred to his mind as constituting the principle of stability, and he hence deduced the necessary velocity. The velocity thus found was exactly equal to that which Herschel subsequently deduced from a course of extremely delicate observations.

The two parts of the ring being placed at different distances from the planet, could not fail to experience, from the action of the sun, different movements of rotation. It would hence seem that the planes of both rings ought to be generally inclined toward each other, whereas they appear from observation always to coincide. It was necessary, then, that some physical cause should exist which would be capable of neutralizing the action of the sun. In a memoir published in February, 1789, Laplace found that this cause must reside in the ellipticity of Saturn, produced by a rapid movement of rotation of the planet, a movement the existence of which Herschel announced in November, 1789.

The reader cannot fail to remark how, on certain occasions, the eyes of the mind can supply the want of the most powerful telescopes, and lead to astronomical discoveries of the highest importance. Let us descend from the heavens upon the earth. The discoveries of Laplace will appear not less important, not less worthy of his genius.

The phenomena of the tides, which an ancient philosopher designated in despair *the tomb of human curiosity*, were connected by Laplace with an analytical theory in which the physical conditions of the question figure for the first time. Accordingly calculators, to the immense advantage of the navigation of our maritime coasts, venture in the present day to predict several years in advance the details of the time and height of the full tides without more anxiety respecting the result than if the question related to the phases of an eclipse.

There exists between the different phenomena of the ebb and flow of the tides and the attractive forces which the sun and moon exercise upon the fluid sheet which covers three-fourths of the globe, an intimate and necessary connection, from which Laplace, by the aid of a series of twenty years of observations, executed at Brest, deduced the value of the mass of our satellite. Science knows in the present day that seventy-five moons would be necessary to form a weight equivalent to that of the terrestrial globe, and it is indebted for this result to an attentive and minute study of the oscillations of the ocean. We know only one means of enhancing the admiration which every thoughtful mind will entertain for theories capable of leading to such conclusions. An historical statement will supply it. In the year 1631, the illustrious Galileo, as appears from his *Dialogues*, was so far from perceiving the mathematical relations from which Laplace deduced results so beautiful, so unequivocal, and so useful, that he taxed with frivolousness the vague idea which Kepler entertained of attributing to the moon's attraction a certain share in the production of the diurnal and periodical movements of the waters of the ocean.

Laplace did not confine himself to extending so considerably, and improving so essentially, the mathematical theory of the tides; he considered the phenomenon from an entirely new point of view; it was he who first treated of the stability of the ocean. Systems of bodies, whether solid or fluid, are subject to two kinds of equilibrium, which we must carefully distinguish from each other. In the case of stable equilibrium, the system, when slightly disturbed, tends always to return to its original condition. On the other hand, when the system is in unstable equilibrium, a very insignificant derangement might occasion an enormous dislocation in the relative positions of its constituent parts.

If the equlibrium of waves is of the latter kind, the waves engendered by the action of winds, by earthquakes, and by sudden movements from the bottom of the ocean, have perhaps risen in past times, and may rise in the future, to the height of the highest mountains. The geologist will have the satisfaction of deducing from these prodigious oscillations a rational explanation of a great multitude of phenomena, but the public will thereby be exposed to new and terrible catastrophes.

Mankind may rest assured; Laplace has proved, that the equilibrium of the ocean is stable, but upon the express condition (which, however, has been amply verified by established facts) that the mean density of the fluid mass is less than the mean density of the earth. Everything else remaining the same, let us substitute an ocean of mercury for the actual ocean, and the stability will disappear, and the fluid will frequently surpass its boundaries, to ravage continents even to the height of the snowy regions which lose themselves in the clouds.

Does not the reader remark how each of the analytical investigations of Laplace serves to disclose the harmony and duration of the universe and of our globe?

It was impossible that the great geometer, who had succeeded so well in the study of the tides of the ocean, should not have occupied his attention with the tides of the atmosphere; that he should not have submitted to the delicate and definitive tests of a rigorous calculus the generally-diffused opinions respecting the influence of the moon upon the height of the barometer and other meteorological phenomena.

Laplace, in effect, has devoted a chapter of his splendid work to an examination of the oscillations which the attractive force of the moon is capable of producing in our atmosphere. It results from these researches that, at Paris, the lunar tide produces no sensible effect upon the barometer. The height of the tide, obtained by the discussion of a long series of observations, has not exceeded two-hundredths of a millimeter, a quantity which, in the present state of meteorological science, is less than the probable error of observation.

The calculation to which I have just alluded may be cited in support of considerations to which I had recourse when I wished to establish, that if the moon alters more or less the height of the barometer, according to its different phases, the effect is not attributable to attraction.

No person was more sagacious than Laplace in discovering intimate relations between phenomena apparently very dissimilar; no person showed himself more skillful in deducing important conclusions from those unexpected affinities.

Toward the close of his days, for example, he overthrew with a stroke of the pen, by the aid of certain observations of the moon, the cosmogonic theories of Buffon and Bailly, which were so long in favor. According to these theories, the earth was inevitably advancing to a state of congelation which was close at hand. Laplace, who never contented himself with a vague statement, sought to determine in numbers the rapid cooling of our globe which Buffon had so eloquently but so gratuitously announced. Nothing could be more simple, better connected, or more demonstrative than the chain of deductions of the celebrated geometer.

A body diminishes in volume when it cools. According to the most elementary principles of mechanics, a rotating body which contracts in dimensions ought inevitably to turn upon its axis with greater and greater rapidity. The length of the day has been determined in all ages by the time of the earth's rotation; if the earth is cooling, the length of the day must be continually shortening. Now, there exists a means of ascertaining whether the length of the day has undergone any variation; this consists in examining, for each century, the arc of the celestial sphere described by the moon during the interval of time which the astronomers of the existing epoch called a day; in other words, the time required by the earth to effect a complete rotation on its axis, the velocity of the moon being, in fact, independent of the time of the earth's rotation.

Let us now, after the example of Laplace, take from the standard tables the least considerable values, if you choose, of the expansions or contractions which solid bodies experience from changes of temperature; search then the annals of Grecian, Arabian, and modern astronomy for the purpose of finding in them the angular velocity of the moon, and the great geometer will prove, by incontrovertible evidence, founded upon these data, that during a period of 2,000 years the mean temperature of the earth has not varied to the extent of the hundredth part of a degree of the centigrade thermometer. No eloquent declamation is capable of resisting such a process of reasoning, or withstanding the force of such numbers. The mathematics have been in all ages the implacable adversaries of scientific romances.

The fall of bodies, if it was not a phenomenon of perpetual occurrence, would justly excite in the highest degree the astonishment of mankind. What, in effect, is more extraordinary than to see an inert mass—that is to say, a mass deprived of will, a mass which ought not to have any propensity to advance in one direction more than in another, precipitate itself toward the earth as soon as it ceased to be supported?

Nature engenders the gravity of bodies by a process so recondite, so completely beyond the reach of our senses and the ordinary resources of human intelligence, that the philosophers of antiquity, who supposed that they could explain everything mechanically according to the simple evolutions of atoms, excepted gravity from their speculations.

Descartes attempted what Leucippus, Democritus, Epicurus, and their followers thought to be impossible. He made the fall of terrestrial bodies depend upon the action of a vortex of very subtle matter circulating around the earth. The real improvements which the illustrious Huyghens applied to the ingenious conception of our countryman were far, however, from imparting to it clearness and precision, those characteristic attributes of truth.

Those persons form a very imperfect estimate of the meaning of one of the greatest questions which have occupied the attention of modern inquirers, who regard Newton as having issued victorious from a struggle in which his two immortal predecessors had failed. Newton did not discover the cause of gravity any more than Galileo did. Two bodies placed in juxtaposition approach each other. Newton does not inquire into the nature of the force which produces this effect. The force exists. He designates it by the term attraction; but, at the same time, he warns the reader that the term, as thus used by him, does not imply any definite idea of the physical process by which gravity is brought into existence and operates.

The force of attraction being once admitted as a fact, Newton studies it in all terrestrial phenomena, in the revolutions of the moon, the planets, satellites, and comets; and, as we have already stated, he deduced from this incomparable study the simple, universal, mathematical characteristics of the forces which preside over the movements of all the bodies of which our solar system is composed.

The applause of the scientific world did not prevent the immortal author of the *Principia* from hearing some persons refer the principle of gravitation to the class of occult qualities. This circumstance induced Newton and his most devoted followers to abandon the reserve which they had hitherto considered it their duty to maintain. Those persons were then charged with ignorance who regarded attraction as an essential property of matter, as the mysterious indication of a sort of charm; who supposed that two bodies may act upon each other without the intervention of a third body. This force was then either the result of the tendency of an ethereal fluid to move from the free regions of space, where its density is a maximum, toward the planetary bodies, around which there exists a greater degree of rarefaction, or the consequence of the impulsive force of some fluid medium.

Newton never expressed a definitive opinion respecting the origin of the impulse which occasioned the attractive force of matter—at least in our solar system. But we have strong reasons for supposing, in the present day, that, in using the word *impulse* the great geometer was thinking of the systematic ideas of Varignon and Fatio de Duillier, subsequently re-invented and perfected by Lesage. These ideas, in effect, had been communicated to him before they were published to the world.

According to Lesage, there are in the regions of space bodies moving in every possible direction, and with excessive rapidity. The author applied to these the name of ultramundane corpuscules. Their totality constituted the gravitative fluid, if indeed the designation of a fluid be applicable to an assemblage of particles having no mutual connection. A single body placed in the midst of such an ocean of movable particles would remain at rest although it were impelled equally in every direction. On the other hand, two bodies ought to advance toward each other, since they would serve the purpose of mutual screens, since the surfaces facing each other would no longer be hit in the direction of their line of junction by the ultra-mundane particles, since there would then exist currents, the effect of which would no longer be neutralized by opposite currents. It will be easily seen, besides, that two bodies plunged into the gravitative fluid would tend to approach each other with an intensity which would vary in the inverse proportion of the square of the distance.

If attraction is the result of the impulse of a fluid, its action ought to employ a finite time in traversing the immense spaces which separate the celestial bodies. If the sun, then, were suddenly extinguished, the earth, after the catastrophe, would, mathematically speaking, still continue for some time to experience its attractive influence. The contrary would happen on the occasion of the sudden birth of a planet: a certain time would elapse before the attractive force of the new body would make itself felt on the earth.

Several geometers of the last century were of opinion that the force of attraction is not transmitted instantaneously from one body to another; they even assigned to it a comparatively inconsiderable velocity of propagation. Daniel Bernoulli, for example, in attempting to explain how the spring-tide arrives upon our coasts a day and a half after the syzygies, that is to say, a day and a half after the epochs when the sun and moon are most favorably situated for the production of this magnificent phenomenon, assumed that the disturbing force required all this time (a day and a half) for its propagation from the moon to the ocean. So feeble a velocity was inconsistent with the mechanical explanation of attraction, of which we have just spoken. The explanation, in effect, necessarily supposes that the proper motions of the celestial bodies are insensible, compared with the motion of the gravitative fluid. After having discovered that the diminution of the eccentricity of the terrestrial orbit is the real cause of the observed acceleration of the motion of the moon, Laplace, on his part, endeavored to ascertain whether this mysterious acceleration did not depend on the gradual propagation of attraction.

The result of calculation was at first favorable to the plausibility of the hypothesis. It showed that the gradual propagation of the attractive force would introduce into the movement of our satellite a perturbation proportional to the square of the time which elapsed from the commencement of any epoch; that in order to represent numerically the results of astronomical observations, it would not be necessary to assign a feeble velocity to attraction; that a propagation eight millions of times more rapid than that of light would satisfy all the phenomena.

Although the true cause of the acceleration of the moon is now well known, the ingenious calculation of which I have just spoken does not the less on that account maintain its place in science. In a mathematical point of view, the perturbation depending on the gradual propagation of the attractive force which this calculation indicates has a certain existence. The connection between the velocity of perturbation and the resulting inequality is such that one of the two quantities leads to a knowledge of the numerical value of the other. Now, upon assigning to the inequality the greatest value which is consistent with the observations after they have been corrected for the effect due to the variation of the eccentricity of the terrestrial orbit, we find the velocity of the attractive force to be fifty millions of times the velocity of light.

If it be borne in mind that this number is an inferior limit, and that the velocity of the rays of light amounts to 77,000 leagues (192,000 English miles) per second, the philosophers who profess to explain the force of attraction by the impulsive energy of a fluid, will see what prodigious velocities they must satisfy.

The reader cannot fail again to remark the sagacity with which Laplace singled out the phenomena which were best adapted for throwing light upon the most obscure points of celestial physics; nor the success with which he explored their various parts, and deduced from them numerical conclusions in presence of which the mind remains confounded.

The author of the *Mécanique Céleste* supposed, like Newton, that light consists of material molecules of excessive tenuity and endued in empty space with a velocity of 77,000 leagues in a second. However, it is right to warn those who would be inclined to avail themselves of this imposing authority that the principal argument of Laplace in favor of the system of emission consisted in the advantage which it afforded of submitting every question to a process of simple and rigorous calculation; whereas, on the other hand, the theory of undulations has always offered immense difficulties to analysts. It was natural that a geometer who had so elegantly connected the laws of simple refraction which light undergoes in its passage through the atmosphere, and the laws of double refraction which it is subject to in the course of its passage through certain crystals, with the action of attractive and repulsive forces, should not have abandoned this route, before he recognized the impossibility of arriving by the same path at plausible explanations of the phenomena of diffraction and polarization. In other respects, the care which Laplace always employed in pursuing his researches, as far as possible, to their numerical results will enable those who are disposed to institute a complete comparison between the two rival theories of light to derive from the *Mécanique Céleste* the materials of several interesting relations.

Is light an emanation from the sun? Does this body launch out incessantly in every direction a part of its own substance? Is it gradually diminishing in volume and mass? The attraction exercised by the sun upon the earth will, in that case, gradually become less and less considerable. The radius of the terrestrial orbit, on the other hand, cannot fail to increase, and a corresponding effect will be produced on the length of the year.

This is the conclusion which suggests itself to every person upon a first glance at the subject. By applying analysis to the question, and then proceeding to numerical computations, founded upon the most trustworthy results of observation relative to the length of the year in different ages, Laplace has proved that an incessant emission of light, going on for a period of two thousand years, has not diminished the mass of the sun by the two-millionth part of its original value.

Our illustrious countryman never proposed to himself anything vague or indefinite. His constant object was the explanation of the great phenomena of nature, according to the inflexible principles of mathematical analysis. No philosopher, no mathematician, could have maintained himself more cautiously on his guard against a propensity to hasty speculation. No person dreaded more the scientific errors which the imagination gives birth to, when it ceases to remain within the limits of facts, of calculation, and of analogy. Once, and once only, did Laplace launch forward, like Kepler, like Descartes, like Leibnitz, like Buffon, into the region of conjectures. His conception was not then less than a cosmogony.

All the planets revolve around the sun, from west to east, and in planes which include angles of inconsiderable magnitude. The satellites revolve around their respective primaries in the same direction as that in which the planets revolve around the sun, that is to say, from west to east.

The planets and satellites which have been found to have a rotatory motion, turn also upon their axes from west to east. Finally, the rotation of the sun is also directed from west to east. We have here, then, an assemblage of forty-three movements, all operating in the same direction. By the calculus of probabilities, the odds are four thousand millions to one that this co-incidence in the direction of so many movements is not the effect of accident.

It was Buffon, I think, who first attempted to explain this singular feature of our solar system. Having wished in the explanation of phenomena to avoid all recourse to causes which were not warranted by nature, the celebrated academician investigated a physical origin of the system in what was common to the movements of so many bodies differing in magnitude, in form, and in distance from the principal center of attraction. He imagined that he discovered such an origin by making this triple supposition: A comet fell obliquely upon the sun; it pushed before it a torrent of fluid matter; this substance transported to a greater or less distance from the sun, according to its mass, formed by concentration all the known planets.

The bold hypothesis of Buffon is liable to unsurmountable difficulties. I proceed to indicate, in a few words, the cosmogonic system which Laplace substituted for that of the illustrious author of the *Histoire Naturelle.*

According to Laplace, the sun was at a remote epoch the central nucleus of an immense nebula, which possessed a very high temperature, and extended far beyond the region in which Uranus revolves in the present day. No planet was then in existence.

The solar nebula was endued with a general movement of revolution directed from west to east. At it cooled it could not fail to experience a gradual condensation, and, in consequence, to rotate with greater and greater rapidity. If the nebulous matter extended originally in the plane of the equator as far as the limit at which the centrifugal force exactly counterbalanced the attraction of the nucleus, the molecules situate at this limit ought, during the process of condensation, to separate from the rest of the atmospheric matter, and form an equatorial zone, a ring revolving separately and with its primitive velocity.

We may conceive that analogous separations were effected in the higher strata of the nebula at different epochs, that is to say, at different distances from the nucleus, and that they give rise to a succession of distinct rings, included almost in the same plane and endued with different velocities.

This being once admitted, it is easy to see that the indefinite stability of the rings would have required a regularity of structure throughout their whole contour which is very improbable. Each of them accordingly broke in its turn into several masses, which were plainly endued with a movement of rotation, coinciding in direction with the common movement of revolution, and which in consequence of their fluidity assumed spheroidal forms.

In order, then, that one of those spheroids might absorb all the others belonging to the same ring, it will be sufficient to assign to it a mass greater than that of any other spheroid.

Each of the planets, while in the vaporous condition to which we have just alluded, would manifestly have a central nucleus gradually increasing in magnitude and mass, and an atmosphere offering, at its successive limits, phenomena entirely similar to those which the solar atmosphere, properly so called, had exhibited. We here witness the birth of satellites, and that of the ring of Saturn.

The system of which I have just given an imperfect sketch has for its object to show how a nebula endued with a general movement of rotation must eventually transform itself into a very luminous central nucleus (a sun) and into a series of distinct spheroidal planets, situate at considerable distances from each other, revolving all around the central sun in the direction of the original movement of the nebula; how these planets ought also to have movements of rotation operating in similar directions; how, finally, the satellites, when any of such are formed, cannot fail to revolve upon their axes and around their respective primaries, in the direction of rotation of the planets and of their movement of revolution around the sun.

We have just found, conformably to the principles of mechanics, the forces with which the particles of the nebula were originally endued, in the movements of rotation and revolution of the compact and distinct masses which these particles have brought into existence by their condensation. But we have thereby achieved only a single step. The primitive movement of rotation of the nebula is not connected with the simple attraction of the particles. This movement seems to imply the action of a primordial impulsive force.

Laplace is far from adopting, in this respect, the almost universal opinion of philosophers and mathematicians. He does not suppose that the mutual attractions of originally immovable bodies must ultimately reduce all the bodies to a state of rest around their common center of gravity. He maintains, on the contrary, that three bodies, in a state of rest, two of which have a much greater mass than the third, would concentrate into a single mass only in certain exceptional cases. In general, the two most considerable bodies would unite together, while the third would revolve around their common center of gravity. Attraction would thus become the cause of a sort of movement which would seem to be explicable solely by an impulsive force.

It might be supposed, indeed, that in explaining this part of his system Laplace had before his eyes the words which Rousseau has placed in the mouth of the Vicar of Savoy, and that he wished to refute them. "Newton has discovered the law of attraction," says the author of *Emile;* "but attraction alone would soon reduce the universe to an immovable mass. With this law we must combine a projectile force in order to make the celestial bodies describe curve-lines. Let Descartes reveal to us the physical law which causes his vortices to revolve; and let Newton show us the hand which launched the planets along the tangents of their orbits."

According to the cosmogonic ideas of Laplace, comets did not originally form part of the solar system. They are not formed at the expense of the matter of the immense solar nebula. We must consider them as small wandering nebula, which the attractive force of the sun has caused to deviate from their original route. Such of those comets as penetrated into the great nebula at the epoch of condensation and of the formation of planets fell into the sun, describing spiral curves, and must by their action have caused the planetary orbits to deviate more or less from the plane of the solar equator, with which they would otherwise have exactly coincided.

With respect to the zodiacal light, that rock against which so many reveries have been wrecked, it consists of the most volatile parts of the primitive nebula. These molecules, not having united with the equatorial zones, successively abandoned in the plane of the solar equator, continue to revolve at their original distances, and with their original velocities. The circumstance of this extremely rare substance being included wholly within the earth's orbit, and even within that of Venus, seemed irreconcilable with the principles of mechanics; but this difficulty occurred only when the zodiacal substance being conceived to be in a state of direct and intimate dependence on the solar photosphere, properly so called, an angular movement of rotation was impressed on it equal to that of the photosphere, a movement in virtue of which it effected an entire revolution in twenty-five days and a half. Laplace presented his conjectures on the formation of the solar system with the diffidence inspired by a result which was not founded upon calculation and observation.*

Perhaps it is to be regretted that they did not receive a more complete development, especially in so far as it concerns the division of the matter into distinct rings; perhaps it would have been desirable if the illustrious author had expressed himself more fully respecting the primitive physical condition, the molecular condition of the nebula at the expense of which the sun, planets, and satellites of our system were formed. It is perhaps especially to be regretted that Laplace should have only briefly alluded to what he considered the obvious possibility of movements of revolution having their origin in the action of simple attractive forces, and to other questions of a similar nature.

Notwithstanding these defects, the ideas of the author of the *Mécanique Céleste* are still the only speculations of the kind which, by their magnitude, their coherence, and their mathematical character, may be justly considered as forming a physical cosmogony; those alone which in the present day derive a powerful support from the results of the recent researches of astronomers on the nebulæ of every form and magnitude which are scattered throughout the celestial vault.

In this analysis, we have deemed it right to concentrate all our attention upon the *Mécanique Céleste.* The *Système du Monde* and the *Théorie Analytique des Probabilités* would also require detailed notices. The *Exposition du Système du Monde* is the *Mécanique Céleste* divested of the great apparatus of analytical formula which ought to be attentively perused by every astronomer who, to use an expression of Plato, is desirous of knowing the numbers which govern the physical universe. It is in the *Exposition du Système du Monde* that persons unacquainted with mathematical studies will obtain an exact and competent knowledge of the methods to which physical astronomy is indebted for its astonishing progress. This work, written with a noble simplicity of style, an exquisite propriety of expression, and a scrupulous accuracy, is terminated by a sketch of the history of astronomy, universally ranked in the present day among the finest monuments of the French language.

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* Laplace has explained this theory in his *Exposition du Système du Monde,* (*liv.* 4, note 7.)—TRANSLATOR.

A regret has been often expressed that Cæsar, in his immortal *Commentaries*, should have confined himself to a narration of his own campaigns; the astronomical commentaries of Laplace ascend to the origin of communities. The labors undertaken in all ages for the purpose of extracting new truths from the heavens are there justly, clearly, and profoundly analyzed; it is genius presiding as the impartial judge of genius. Laplace has always remained at the height of his great mission; his work will be read with respect so long as the torch of science shall continue to throw any light.

The calculus of probabilities, when confined within just limits, ought to interest, in an equal degree, the mathematician, the experimentalist, and the statesman. From the time when Pascal and Fermat established its first principles, it has rendered, and continues daily to render, services of the most eminent kind. It is the calculus of probabilities, which, after having suggested the best arrangements of the tables of population and mortality, teaches us to deduce from those numbers, in general so erroneously interpreted, conclusions of a precise and useful character; it is the calculus of probabilities which alone can regulate justly the premiums to be paid for assurances; the reserve funds for the disbursement of pensions, annuities, discounts, &c. It is under its influence that lotteries and other shameful snares cunningly laid for avarice and ignorance have definitively disappeared. Laplace has treated these questions, and others of a much more complicated nature, with his accustomed superiority. In short, the *Théorie Analytique des Probabilités* is worthy of the author of the *Mécanique Céleste.*

A philosopher, whose name is associated with immortal discoveries, said to his audience, who had allowed themselves to be influenced by ancient and consecrated authorities, "Bear in mind, gentlemen, that in questions of science the authority of a thousand is not worth the humble reasoning of a single individual." Two centuries have passed over their words of Galileo, without depreciating their value or obliterating these truthful character. Thus, instead of displaying a long list of illustrious admirers of the three beautiful works of Laplace, we have preferred glancing briefly at some of the sublime truths which geometry has there deposited. Let us not, however, apply this principle in its utmost rigor, and since chance has put into our hands some unpublished letters of one of those men of genius, whom nature has endowed with the rare faculty of seizing at a glance the salient points of an object, we may be permitted to extract from them two or three brief and characteristic appreciations of the *Mécanique Céleste* and the *Traité des Probabilités.*

On the 27th Vendémiaire, in the year X, General Bonaparte, after having received a volume of the *Mécanique Céleste*, wrote to Laplace in the following terms: "The first *six months* which I shall have at my disposal will be employed in reading your beautiful work." It would appear that the words, "the first *six months*," deprive the phrase of the character of a common-place expression of thanks, and convey a just appreciation of the importance and difficulty of the subject-matter.

On the 5th Frimaire, in the year XI, the reading of some chapters of the volume which Laplace had dedicated to him was to the general "a new occasion for regretting that the force of circumstances had directed him into a career which removed him from the pursuit of science."

"At all events," added he, "I have a strong desire that future generations, upon reading the *Mécanique Céleste*, shall not forget the esteem and friendship which I have entertained toward its author."

On the 17th Prairial, in the year XIII, the general, now become Emperor, wrote from Milan: "The *Mécanique Céleste* appears to me destined to shed new luster on the age in which we live."

Finally, on the 12th of August, 1812, Napoleon, who had just received the *Traité du Calcul des Probabilités* wrote from Witepask the letter which we transcribe textually:

"There was a time when I would have read with interest your Traité *du Calcul des Probabilités*. For the present, I must confine myself to expressing to you the satisfaction which I experience every time that I see you give to the world new works which serve to improve and extend the most important of the sciences and contribute to the glory of the nation. The advancement and the improvement of mathematical science are connected with the prosperity of the state."

I have now arrived at the conclusion of the task which I had imposed upon myself. I shall be pardoned for having given so detailed an exposition of the principal discoveries for which philosophy, astronomy, and navigation are indebted to our geometers.

It has appeared to me that in thus tracing the glorious past, I have shown our contemporaries the full extent of their duty towards the country. In fact, it is for nations especially to bear in remembrance the ancient adage, *noblesse oblige*.

APPENDIX A.

The following is a brief notice of some other interesting results of the researches of Laplace which have not been mentioned in the text:

Method for determining the orbits of comets.—Since comets are generally visible only during a few days or weeks at the utmost, the determination of their orbits is attended with peculiar difficulties. The method devised by Newton for effecting this object was in every respect worthy of his genius. Its practical value was illustrated by the brilliant researches of Halley on cometary orbits. It necessitated, however, a long train of tedious calculations, and, in consequence, was not much used, astronomers generally preferring to attain the same end by a tentative process. In the year 1780, Laplace communicated to the

Academy of Sciences an analytical method for determining the elements of a comet's orbit. This method has been extensively employed in France. Indeed, previously to the appearance of Olbers's method, about the close of the last century, it furnished the easiest and most expeditious process hitherto devised for calculating the parabolic elements of a comet's orbit.

Invariable plane of the solar system.—In consequence of the mutual perturbations of the different bodies of the planetary system, the planes of the orbits in which they revolve are perpetually varying in position. It becomes, therefore, desirable to ascertain some fixed plane to which the movements of the planets in all ages may be referred, so that the observations of one epoch might be rendered readily comparable with those of another. This object was accomplished by Laplace, who discovered that notwithstanding the perpetual fluctuations of the planetary orbits, there exists a fixed plane, to which the positions of the various bodies may at any instant be easily referred. This plane passes through the center of gravity of the solar system, and its position is such that if the movements of the planets be projected upon it, and if the mass of each planet be multiplied by the area which it describes in a given time, the sum of such products will be a maximum. The position of the plane for the year 1750 has been calculated by referring it to the ecliptic of that year. In this way it has been found that the inclination of the plane is 1° 35′ 31″, and that the longitude of the ascending node is 102° 57′ 30″. The position of the plane when calculated for the year 1950, with respect to the ecliptic of 1750, gives 1° 35′ 31″ for the inclination, and 102° 57′ 15″ for the longitude of the ascending node. It will be seen that a very satisfactory accordance exists between the elements of the position of the invariable plane for the two epochs.

Diminution of the obliquity of the ecliptic.—The astronomers of the eighteenth century had found, by a comparison of ancient with modern observations, that the obliquity of the ecliptic is slowly diminishing from century to century. The researches of geometers on the theory of gravitation had shown that an effect of this kind must be produced by the disturbing action of the planets on the earth. Laplace determined the secular displacement of the plane of the earth's orbit due to each of the planets, and in this way ascertained the whole effect of perturbation upon the obliquity of the ecliptic. A comparison which he instituted between the results of his formula and an ancient observation recorded in the Chinese Annals exhibited a most satisfactory accordance. The observation in question indicated the obliquity of the ecliptic for the year 1100 before the Christian era to be 23° 54′ 2″·5. According to the principles of the theory of gravitation, the obliquity for the same epoch would be 23° 51′ 30″.

Limits of the obliquity of the ecliptic modified by the action of the sun and moon upon the terrestrial spheroid.—The ecliptic will not continue indefinitely to approach the equator. After attaining a certain limit, it will then vary in the opposite direction, and the obliquity will continually increase in like manner as it previously diminished. Finally, the inclination of the equator and the ecliptic will attain a certain maximum value, and then the obliquity will again diminish. Thus the angle contained between the two planes will perpetually oscillate within certain limits. The extent of variation is inconsiderable. Laplace found that, in consequence of the spheroidal figure of the earth, it is even less than it would otherwise have been. This will be readily understood, when we state that the disturbing action of the sun and moon upon the terrestrial spheroid produces an oscillation of the earth's axis which occasions a periodic variation of the obliquity of the ecliptic. Now, as the plane of the ecliptic approaches the equator, the mean disturbing action of the sun and moon upon the redundant matter accumulated around the latter will undergo a corresponding variation, and hence will arise an inconceivably slow movement of the plane of the equator, which will necessarily affect the obliquity of the ecliptic. Laplace found that if it were not for this cause, the obliquity of the ecliptic would oscillate to the extent of 4° 53′ 33″ on each side of a mean value, but that when the movements of both planes are taken into acccunt, the extent of oscillation is reduced to 1° 33′ 45″.

Variation of the length of the tropical year.—The disturbing action of the sun and moon upon the terrestrial spheroid occasions a continual *regression* of the equinoctial points, and hence arises the distinction between the sidereal and tropical year. The effect is modified in a small degree by the variation of the plane of the ecliptic, which tends to produce a *progression* of the equinoxes. If the movement of the equinoctial points arising from these combined causes was uniform, the length of the tropical year would be manifestly invariable. Theory, however, indicates that for ages past the rate of regression has been slowly increasing, and consequently the length of the tropical year has been gradually diminishing. The rate of diminution is exceedingly small. Laplace found that it amounts to somewhat less than half a second in a century. Consequently the length of the tropical year is now about ten seconds less than it was in the time of Hipparchus.

Limits of variation of the tropical year modified by the disturbing action of the sun and moon upon the terrestrial spheroid.—The tropical year will not continue indefinitely to diminish in length. When it has once attained a certain minimum value, it will then increase, until finally having attained an extreme value in the opposite direction, it will again begin to diminish, and thus it will perpetually oscillate between certain fixed limits. Laplace found that the extent to which the tropical year is liable to vary from this cause amounts to 38 seconds. If it were not for the effect produced upon the inclination of the equator to the ecliptic by the mean disturbing action of the sun and moon upon the terrestrial spheroid, the extent of variation would amount to 162 seconds.

Motion of the perihelion of the terrestrial orbit.—The major axis of the orbit of each planet is in a state of continual movement from the disturbing action of the other planets. In some cases it makes the complete tour of the heavens; in others it merely oscillates around a mean position. In the case of the earth's orbit, the perihelion is slowly advancing in the same direction as that in which all the planets are revolving around the sun. The alteration of its position with respect to the stars amounts to about 11″ in a year, but since the equinox is regressing in the opposite direction at the rate of 50″ in a year, the whole annual variation of the longitude of the terrestrial perihelion amounts to 61″. Laplace has considered two remarkable epochs in connection with this fact, viz, the epoch at which the major axis of the earth's orbit co-incided with the line of the equinoxes, and the epoch at which it stood perpendicular to that line. By calculation he found the former of these epochs to be referable to the year 4107 B. C., and the latter to the year 1245 A. D. He accordingly suggested that the latter should be used as a universal epoch for the regulation of chronological occurrences.

EULOGY ON QUETELET.

ABSTRACT OF AN ESSAY UPON HIS LIFE AND WORKS, BY ED. MAILLY.

[Translated for the Smithsonian Institution from the *Annuaire de l'Académie royale* of Belgium for 1875.]

Lambert Adolphe Quetelet was born at Ghent on the 22d of February, 1796. He was educated at the lyceum of his native town, and early showed that nature had endowed him, not only with a vivid imagination and a mind of power, but also with the precious gift of indomitable perseverance. He carried away all the prizes of his school, and at the same time wrote poetry which attracted considerable attention. He also manifested a talent for art, and a drawing of his gained the first prize at the lyceum of Ghent in 1812.

Having lost his father when only seven years of age, and his family not being able to support him, he was obliged, as soon as he had completed his course at the lyceum, to enter, as a teacher, the institution for public instruction at Audenarde. Here he remained a year, teaching mathematics, drawing, and grammar; he was then given a mastership in his native town. In 1815 the lyceum at Ghent, by order of the municipal council, was converted into a university, and Quetelet was appointed professor of mathematics. He received his nomination on his nineteenth birthday. There was nothing brilliant in the lot which had thus far fallen to him, but it secured the means of existence, and left him at liberty to devote himself to art, literature, and science.

His most intimate companion, with whom he shared all his tastes, was G. Dandelin, who had been his fellow-pupil at the lyceum. The two friends at one time appear to have been seized with a dramatic furor, and, with the assistance of a distinguished musician, composed a grand prose opera in one act, called "*John the Second, or Charles the Fifth, in the walls of Ghent.*" It was represented in the theater of Ghent, on the 18th of December, 1816. Its success appears to have been moderate, since it was only played twice, and was withdrawn on the plea that it excited the galleries too much. Be this as it may, with it ended the dramatic career of the authors. They had, however, in preparation, two other pieces, *The Two Troubadours* and *The Jester*, but before the completion of these Dandelin was appointed second lieutenant of engineers, and ordered to Namur, while Quetelet was won back to the pursuit of science through the influence of his associate, Professor Garnier.

In 1819 he passed his examination and received the degree of Doctor of Science, the first conferred by the new university. In honor of the event he gave a banquet, which was attended by many of the public functionaries, as well as the professors and pupils of the university.

His inaugural address gave brilliant promise of his future success. It was divided into two parts: In the first he showed that the locus of the centers of a series of circles, tangents to two given circles of position, is always a conic section; in the second he exhibited a new curve of the third degree, the *focale*, the locus of the foci of all the conic sections, determined by a transversal plane, revolving around a certain point, upon the surface of a vertical cone. The discovery of this curve was an important addition to mathematics, and the term *focale* is as inseparably connected with the name of Quetelet, as *cycloid* with that of his favorite author Pascal. Among the themes he submitted to the university in addition to his address, was a Latin essay upon the question whether aerolites are projected from the moon.

On the occasion of the laying of the corner-stone of the university buildings, a banquet was given, preceded by a literary meeting, at which was read a poem by Quetelet upon the death of Grétry. This production, full of beautiful versification and expressions of exquisite sensibility, procured for him an introduction to M. Falk, minister of public instruction, who, with the interest excited by a young man at once a poet and a geometer, a man of letters and of science, caused him to be nominated to a professorship at the Athenæum of Brussels.

His first act on arriving at Brussels was to pay his respects to Commandant Nieuport, then in his seventy-third year, and who might be said to be the only representative of the exact sciences in Belgium. He had read the inaugural address of the young doctor, and appreciated, as it deserved, the discovery of the focale. Stimulated by the encouragement he received, Quetelet continued his labors in this direction, and published in 1819, in the *Annales Belgique*, an article under the title of *Some new properties of the focale and of some other curves*. This was favorably noticed by Garnier, his former preceptor at Ghent, and procured his election as a member of the Belgian Academy on the 1st of February, 1820. He was then twenty-four years of age.

He soon won the high regard of his associates in the academy, among whom were the talented Cornelissen and the renowned chemist Van Mons, whose niece he afterward married. The first use he made of his influence was to procure the election of his friend Dandelin and of Baron Reiffenberg, third regent of the athenæum, afterward professor of philosophy at the university of Louvain. The latter lodged in the same house with Quetelet, and soon became ardently attached to him. He was in intimate intercourse and a great favorite with the French refugees then in Brussels, and introduced to them his new friend. Among them were such men as David, Arnault, Bory de Saint Vincent, Berlier, Merlin, &c., who, if they had been won by the ready and brilliant wit of Reiffenberg, were equally attracted by the more solid qualities of Quetelet. His relations with the refugees did not, however, prevent him from forming other associations; he sought out and made friends of the artists of the city, joined a literary society which had just been formed, and became a member of the reading committee for the royal theaters. In the latter capacity he had free access to a stage which was favored each year by Talma, Mlle. Mars, and the principal French comedians of the day.

The literary society published annually a poetical almanac, the twentieth and last volume of which appeared in 1825, when the society quietly ceased to exist. Quetelet was a contributor, and, as his poetical life seems also to have ended about this time, it may be well to notice here some of the pieces published by him since the *Eulogy on Grétry*. The article entitled "*The last moments*" resembles somewhat, but is inferior to, the "*Farewell of the poet to his lamp*," one of his best pieces. "*The 19th of January, or the night-watch of the ladies*," contains some charming lines. An ode to Tollens is in the style of Horace, the favorite poet of Quetelet. An ode to Odevare, a painter, greatly admired in 1821, although now but little known, is much more elevated in character. *The investiture of the principality of Orange, given by Charlemagne to William the Cornet*, was also ably treated in verse by our associate. Works of the imagination, whether in prose or verse, greatly interested Quetelet. His "*Essay upon Romance*," published in 1823 in *Belgic Annals*, has lost none of its interest, and, with his poetry, ought to be reprinted. He studied the romances of different nations, translated into verse Schiller's tale called "The Knight of Toggenburg," and into prose various Spanish and English ballads.

He had no predilection for the classical, in literature or art, and says, of modern painting, "The pictures of antiquity, full of life and genius as they are, can never produce in our minds the illusive effect they had upon the Greeks and the Romans. Flora, Zephyr, Venus, so charming in their pictures, are seldom so in ours. It is no doubt good to be the echo of antiquity, but only those can understand the sounds repeated who can go back to past ages and assume for the moment their religion and national character. Let us imitate the Greeks in their simplicity and in their admirable portraiture of nature, but let us have, as they did, our own heroes, our groves, and our religion. What would the age of Pericles have said if Euripides and Sophocles had represented only Osirus or the mysterious *fêtes* of the Egyptians?"

"*The Lords of the Castle*" and "*The Countess Ida*," (fables,) "*My Little Boat*," an allegorical ballad, dedicated to M. Falk, an elegy upon the death of Adolph Delemer, an ode to Orion, translated from the Dutch of Nieuland, a translation of a portion of Byron's "*Siege of Corinth*," and the "*Scald and Lysis*," a romance, are among others of his poetical pieces worthy of mention. The latter was commended by the classic Raoul in the "*Belgic Mercury*." He says, in reference to it, "Quetelet, with whom poetry is only a relaxation, writes verse with great facility. He is of the number of those who illustrate the truth that the muses are sisters."

We have endeavored to give some idea of Quetelet as a poet, a man of letters, and a geometer, and before proceeding to consider him as a physicist, astronomer, and statistician we shall see how he filled the office of professor. When first appointed to the Athenæum of Brussels, he occupied only a very subordinate position, as professor of elementary mathematics, but he was soon promoted, and his duties much extended. In 1824 we find him teaching at the athenæum the descriptive geometry of Menge, the theory of shades and perspective, the calculation of probabilities of La Croix, higher algebra, and analytical geometry; while he was also giving a public course of lectures at the museum upon experimental physics, the elements of astronomy, and of differential and integral calculus.

He was very highly esteemed by his pupils. There was something about him at once imposing and amiable, while there was a complete absence of anything like pedantry or haughtiness. Although marked with small-pox, his physiognomy was refined and impressive; it was only necessary to fix his large dark eyes, surmounted with heavy black brows, upon the refractory, to insure at once silence and submission. On account of the inefficiency of his assistants, he was obliged each year to commence arithmetic, algebra, and geometry. He separated his pupils, according to their ability, into two classes, occupying adjoining rooms, and he would pass from one to the other apartment, experiencing no difficulty in preserving silence in both. He was as simple and natural in his teaching as in everything else. He reduced arithmetic to a few general principles, and, as soon as he had initiated his pupils in the notation of algebra, showed how this admirable instrument could be used to resolve all ordinary questions relating to numbers. His talent for drawing was displayed by the geometrical figures he formed with chalk upon the blackboard to illustrate his teachings. At the Athenæum his courses attracted numerous auditors from all classes of society. He had a special talent for exposition, and knew how to use to, advantage the few instruments he had at command. He disliked to make experiments with complicated apparatus, which he said was apt to divert the attention from the results exhibited; he considered that only indispensable articles, such as the scales, an electric machine, a voltaic pile, and a few other simple imstruments need be provided.

For the use of his public courses he published several elementary works. The first, upon astronomy, appeared in Paris in 1826. It has been reprinted many times in France and Belgium and translated into several languages. It was followed by one upon natural philosophy, which was intended to enable his pupils at the museum to correct the notes hurriedly taken at the time of the lecture and often erroneous. We have said that he disliked complicated apparatus in teaching the elements of physics, and he accordingly prepared a small volume, the object of which was to describe observations and experiments which could be easily made by any one. This was published in 1832, and the author intended to follow it with other works of the same kind upon magnetism, electricity, light, &c. In 1828 he published a review of the lectures given at the museum upon the calculus of probabilities, as an introduction to his course of physics and astronomy.

The public lectures of Quetelet were such a success that the government considered it advisable to institute other courses of the same kind, and on the third of March, 1827, was installed the *Museum of Science and Letters*, with a corps of efficient professors in the various branches of science and literature. In the review of the lecture with which, three days later, Quetelet opened his course, we find one of his favorite ideas: "The more progress physical sciences make, the more they tend to enter the domain of mathematics, which is a kind of centre to which they all converge. We may even judge of the degree of perfection to which a science has arrived by the facility with which it may be submitted to calculation." The museum continued to exist for eight years. After suffering with all the other educational establishments of the country from the effects of the revolution, it was absorbed into the free university in 1834, and Quetelet ceased his public instruction after twenty years of service. He soon commenced again, however, having been appointed professor of astronomy and geodesy to the military school, by a royal decree, on the 6th of January, 1836. Among his pupils at the Athenæum were the Duke of Saxe Coburg Gotha and the late Prince Consort of England, who always retained a warm affection for his preceptor.

We have said that Quetelet was only twenty-four years of age when made a member of the Brussels Academy. His first contribution, "*A memoir upon a general formula for determining the surface of a polygon, formed on a sphere, by the arcs of great or little circles, disposed in any manner whatever*," was an admirable production. Garnier said of it, that its elegant simplicity and the symmetry of the formula lent interest to a subject which would otherwise have appeared very dry. His second memoir, "*A new theory of conic sections considered in the solid*," did him great honor. His third paper was upon *the paths followed by light and elastic bodies*. We have now come to a subject which occupied much of his attention, to which he devoted three memoirs presented to the academy, and numerous articles in the *Correspondance Mathématique et Physique*—that is, *caustic curves*. In one of those articles he gives the following theorem, which in importance is worthy to be ranked with the discovery of the focale: "The caustic by reflexion, or by refraction for any curve whatever, illuminated by a radiant point, is the development of another curve, which has the property of being the envelope of all the circles, which have their centers upon the reflecting or directing curve, and of which the radii are equal to the distances of the centers from the radiant point in the first case, and proportional to these same distances in the second case; the constant relation being that of the sine of incidence to the sine of refraction." It was easy to extend this theorem to surfaces, considering spheres enveloped instead of circles.

The memoirs presented to the academy were, February 3, 1823, "*Upon circular conchoids;*" November 3, 1825, "*Review of a new theory of caustics followed by different applications to the theory of stereographic projections.*" These researches attracted the attention of Gergonne and other distinguished geometers, and were particularly noticed by the illustrious French mathematician, Chasles, after the *Correspondence Mat. and Phys.* had given them notoriety. We mention two other papers read before the Academy. One, "*A memoir upon some graphical constructions of the planetary orbits,*" and the other "*upon different subjects of geometry of three dimensions,*" presented October 28, 1826.

In 1823 commenced the efforts to found an observatory in Belgium. The especial aptitudes of Quetelet pointed him out as the best person to complete the enterprise, and, thanks to M. Falk, then minister of the interior, he was commissioned to go to Paris to study the practice of astronomy. His own account of his first visit to the observatory may not be uninteresting: "I arrived at Paris near the close of the year 1823, with the prospect of founding an observatory in Belgium, but at the same time with a thorough conviction of my want of knowledge of practical astronomy. I went immediately to the royal observatory, but on entering this building, distinguished by historical associations, I was more than ever oppressed with a sense of my deficiencies. I had not even a letter of introduction to relieve the embarrassment of a first visit. I mounted with sufficient assurance the grand staircase, but when I found myself before the doors of Arago and Bouvard I stood for some time irresolute. I was about to knock at the first, when Bouvard opened his and came out, on his way to the observing-halls. He asked me what I wanted. I at once told him my history, to which the excellent man seemed to listen with interest. He then introduced me to the observing-rooms, into the presence of the great astronomical instruments, to me a novel and wonderful sight. With great kindness he explained their purpose and use, and gave me permission to observe whenever I chose to do so. I availed myself of this permission that very evening, and to my surprise was allowed access, freely and alone, to the instruments and records of the observatory. I came day after day, and always with the same confidence accorded! From time to time the kind Bouvard examined my observations and always with encouraging words. He gradually manifested more and more affection for me, offered to initiate me into the practical calculus of astronomy, and from that time directed all my studies, with a care truly paternal. Not content with these manifestations of kindness, he invited me to his house, presented me to his friends, among others to La Place and Poisson, admitted me to his Friday dinners, and I became in some sort a member of his household." Quetelet remained in Paris several months, and had the honor of being presented to the institute by Alexander von Humboldt. He returned to Brussels on the first of March, 1824.

To fit himself still further for the office of director of the new observatory, he was sent to the principal establishments of the kind in Europe, and on this tour he was accompanied by his wife. He had married on the 20th of September, 1825, the daughter of a French physician, and the niece of the chemist Van Mons. To an intimate acquaintance with the usages of polite society this lady united a ready wit and not inconsiderable literary attainments. She was also an excellent musician. Obliged at an early age to preside in the house of her father, where was congregated the best society of Brussels, she acquired ease and grace of manner, and was well prepared to assist her husband when, in after years, he had arrived at distinction, and exercised a generous hospitality toward the distinguished strangers of every country who visited the observatory. During his journey, Quetelet made the acquaintance of some of the most distinguished men of the age, of Herschel, Schumacher, Grauss, Olders, and others, and at Weimar he had the pleasure of assisting in the celebration of the eightieth birthday of Goethe, with whom he remained eight days. The great poet showed him his experiments in optics, and entertained him with his theory of colors. He was also present at the conference of German naturalists, held at Heidelberg on the 18th of September.

While waiting the completion of his plans in regard to the observatory, he, in conjunction with M. Garnier, established the periodical *La Correspondance Mathématique et Physique*, to which the most eminent men of the age were willing contributors. This publication continued without intermission till 1839, when Quetélet was obliged to resign its supervision on account of the pressing nature of his engagements as permanent secretary to the academy, to which office he had been elected in 1834.

The erection of the observatory was decided upon on the 8th of June, 1826. It was constructed according to the plans of Quetelet, but was not finished till after many vicissitudes, occasioned principally by the political events of 1830. He had been appointed to the directorship in 1818, but the observatory was not completed until 1832. He then immediately commenced his labors, of which it would occupy too much space to give even a list. They included meteorology, terrestrial physics, astronomy, the collection of materials for the *Annales Annuaires* of the observatory, and the other special works in which he has brought together the results of his researches. In the early days of the observatory, all the attention of Quetelet was directed toward meteorology and terrestrial physics. The elements of these two sciences had been almost totally neglected in Belgium, and his first desire was to correct this grave error, a task in which he perfectly succeeded. He has given the results of his persevering observations in his works *Upon the climate of Belgium*, and *Upon the physics of the Globe*, and thus the basis of the meteorology of Belgium was established. The meteorological observations were commenced in 1833, and also the observations for the determination of the latitude and longitude of the establishment. At that time Quetelet possessed only very few and very inferior astronomical instruments. In the month of July, 1835, the meridian telescope and the mural circle were put in position, but the equatorial was not mounted until June of the following year. Quetelet was anxious to have the turning-dome for the equatorial ready in time to observe Halley's comet, the return of which was looked for with great interest by all Europe, but in spite of all his efforts, and the good-will of the government, he was disappointed, and was obliged to follow the course of this eccentric wanderer with only his telescope.

The determination of the difference of longitude between the observatories of Brussels and Greenwich was later a source of great anxiety as well as interest to him, when, in 1853, a trial was made of the new electrical telegraph for this purpose. Two successful attempts of the kind had been made in America, but the distance between the two places, the intervention of the sea, the great reputation of the director of the observatory of Greenwich, and the responsibility assumed before the world, rendered Quetelet very solicitous as to the result of his co-operation, and his anxiety did not cease until the two sealed packets, containing the observations made simultaneously at Greenwich and Brussels, which were by common consent opened on the same day in both places, proved the result to be entirely satisfactory. A similar attempt was made in 1868 between Brussels and Leyden.

At the time the observatory was erected, clocks and watches throughout the country were regulated only by sun-dials, and as these were often defective and liable to get out of order, it frequently happened that there would be a difference in time of from 20 to 25 minutes between the clocks of different towns, and even between those of the same city. The establishment of railroads necessitated more precision, and on the 22d of February, 1836, a royal decree enacted that a meridian should be traced and an instrument of observation be established in forty-one of the principal cities of the kingdom. The execution of this work was intrusted to Quetelet.

From 1841 to 1845 the observatory of Brussels was the center of a vast meteorological net-work, which comprised more than eighty stations in Europe and in the north of Asia. Its director published the results of this great enterprise, with a large number of plates, showing the course and rapidity of the movements of the atmospheric waves. He also made many observations upon the temperature of the earth, and an uninterrupted series of observations of the elements of terrestrial magnetism. But, perhaps, the most remarkable works of Quetelet were the papers he published on his observations of the periodical phenomena of plants and animals. These gave an impulse to similar studies throughout the whole of Europe, and he may on this account be considered as the founder of a new science.

As a class for the study of the fine arts had been added to the academy, and other changes made, it was deemed advisable to form a new institution, and on the 16th of December, 1845, was established *The Royal Academy of Science, Letters, and Fine Arts of Brussels.* The first communication made by Quetelet to the new establishment was upon the history of art in Belgium; the manners and customs of the people at different ages; their habitations, ornaments, furniture, the instruments they used to supply the needs of life, &c. He recommended the formation of an ethnological museum to assist in the study of various types of the human race as well as of their habits, and in 1847, through his instrumentality, was formed the Museum of Antiquities of Belgium.

In 1853 Quetelet was appointed president of the maritime conference held at Brussels on the suggestions of Lieutenant (afterward Captain) Maury. Its purpose was to establish a system of uniform observations at sea.

The regular astronomical observations of the Brussels Observatory commenced in 1836, although the small corps of the establishment, and the attention given to meteorological observations, did not permit of a great field of work. The observations made from 1837 to 1839 furnish in the Annals of the Observatory a catalogue of 666 stars. From 1848 these observations were carried on with renewed ardor; but all the regularity Quetelet desired could not be secured until 1857. From this year a great work has been continued up to the present day. We refer to the catalogue of 10,000 stars, still in preparation, but which will soon be published, completing the monument raised to astronomical science by Adolphe Quetelet, and his son M. Earnest Quetelet, who during nearly eighteen years has shared the work of the observatory, and whose labors have not been interrupted by his father's death.

Adolphe Quetelet contributed greatly to the progress of the study of shooting-stars, about the nature of which little was then known. His attention was first turned to them in 1819, when he wrote his thesis upon the orign of aerolites, and a few years later, he gave, in the first number of the *Correspondance*, a method for determining the height of a meteor from two observations in different places. In 1826 simultaneous observations were organized by his efforts at Brussels, Gand, and Liege. He then abandoned the subject, and did not take it up again until ten years later, when he resumed his observations, and continued them for the rest of his life. He first called attention to the periodicity of the star-showers of the 10th of August, and stimulated astronomers of his own and other countries to make numerous observations, which, taken together, have prepared the way for the remarkable theories now formed as to the character of these interesting meteors. We are indebted to him for very valuable catalogues of their appearances, and also for conscientious and precise researches on their frequency and on the several peculiarities they present.

The direction of the establishment confided to his care did not hinder him from devoting himself to studies of another order, which show the variety of his powers and the habitual industry of his life. We refer to the statistical works, which obtained for him a high place in the world of science. His first memoir upon this subject, *The laws of birth and mortality in Brussels*, was read before the academy on the 4th of June, 1825. "The establishment of life-insurance companies in our provinces," says the author, "and the desire to see these laudable and, if well conducted, benevolent institutions continued among us has induced me to make some researches into the laws of birth and of mortality."

After showing that during the preceding year the births and the deaths had followed almost exactly in the same proportion the variations of the thermometer, only in contrary directions, he gives some tables of mortality and population, with distinction of sex, and shows how they might be made of use in the speculations of the life-insurance companies. Two important remarks appear in the memoir. One, that the annual number of births and of deaths corresponds to a sinusoid, of which the abscissas represent the different times of the year, and the ordinates the number of births or of deaths at these seasons. The other verifies the observation of Malthus, that the number of births increases when through any accidental cause an unusual loss of life has been sustained by a population. Another memoir, in 1827, upon the births, deaths, prisons, and poor-houses of the Pays-Bas, was intended to complete and develop the preceding. It contained another table of mortality for the lower provinces, but without distinction of sex. *Researches upon population* next appeared, and in 1828 *Statistical researches in the kingdom of the Netherlands.* In the importance of the facts given, in breadth of view and novelty of deduction, this memoir is superior to the two preceding. A short introduction gives the origin, aim, resources, and use of statistics, the degree of probability which may be obtained in deductions from them, the uncertainty, which can never be entirely overcome, and the objections of ignorance and false knowledge. The author divides the subject as follows: Extent of the kingdom of the Netherlands; population; imposts and commerce; libraries and daily papers; educational and benevolent institutions; crimes and delinquencies; comparative examination of the different parts of the kingdom. Some of the results obtained are very striking. Thus, in comparing the fecundity of marriage with us and with the English, he says: "Great Britain produces less than our country, but her fruit is more durable. She gives birth to fewer citizens, but she preserves them better. If her fecundity is less, her useful men are more numerous, and generations are not as often renewed to the detriment of the nation. Man during his early years lives at the expense of society. He contracts a debt which he ought some time to pay, and if he fails to do so, his existence has been a loss instead of a gain to his fellow-citizens."

Speaking of criminals and delinquents, he says: "The proportion condemned to the number accused in the criminal and police courts is the same in Belgium and in France; but in the courts of assize the proportion of the condemned to the accused in Belgium is 84 to 100, while in France and England it is only 65; a fact due to the want of the jury in Belgium at the time the observations were made. When that institution was restored, the number of the condemned was reduced to that of France. The author then gives a table indicating the number of crimes committed at different ages, and also giving the amount of what he calls the tendency to crime.

"What is very remarkable," he observes, "is the frightful regularity with which crimes are repeated. Year after year are recorded the same crimes, in the same order, with the same punishments; in the same proportions. Sorrowful condition of the human race! The number condemned to the prison, irons, and the scaffold is as certain as the revenue of the state. We can tell in advance how many individuals will poison their fellows, how many will stain their hands with human blood, how many will be forgers, as surely as we can predict the number of births and of deaths.

During the years 1831 and 1832 Quetelet devoted most of his time to statistical researches, and the five following memoirs were the fruit of his **labors**: *Upon the law of the growth of man; Upon the tendency to crime at different ages; Upon the weight of man at different ages; Upon reproduction and mortality;* and *Statistics of the courts of justice of Belgium from the years* 1826 *to* 1831. The researches in regard to the size and weight of man were new at the time. Quetelet found that the law of growth, at least from birth until the thirteenth year, could be represented by a hyperbola. Twenty years later MM. Bravais and Martins adopted a hyperbola as the curve of the diametrical increase of the Norway pine, which is at least a singular coincidence. In the memoir upon the tendency to crime, he enlarges upon the ideas already given, passes in review the different causes which lead to the development or suppression of this tendency, and denies the favorable influence ordinarily attributed to education. "We too often," he says, "confound moral instruction with the merely learning to read and write, which in many instances only provides new instruments for the commission of crime. On the other hand, as to the injurious moral effects of poverty, some of the provinces of France reputed to be poorest are also the most virtuous.

In connection with these two memoirs he says: "Man, without knowing it, and supposing that he acts of his own free will, is governed by certain laws from which he cannot escape. We may say that the human species, considered as a whole, belongs to the order of physical phenomena. The greater the number, the more the individual will is subordinated to the series of general results which proceed from general causes that control the social condition. These causes ought to be sought out, and only observation can discover them." Man, as the author considers him, is analogous to the center of gravity in a body. "If the average man were determined for a nation, he would represent the type of that nation; if he could be determined for an assembly of all men, he would represent the type of an entire human species. Although his will is restrained within very narrow limits, man contains within him moral forces which distinguish him from the animal, and by which he can, to some extent, modify the laws of nature. These perturbing forces act so slowly that the modifications they produce may be called secular perturbations, since they are analogous to those astronomical variations in the systems of the world which require centuries for their investigation. The study of the natural and perturbing forces of man, in other words, *social mechanics*, would develop laws as admirable as those which govern celestial and inanimate bodies. As to the accusation of materialism, to which these results are said to lead, it has been made so often whenever science has essayed a new step into the unknown regions of nature, that it is not worth while to answer it; especially at the present day, when it can no longer be followed by the rack or imprisonment. Who can justly accuse us of insulting the Divinity, when we exercise the most noble faculties He has given us in meditating upon the sublime laws of the universe, or in endeavoring to make manifest the admirable economy and infinite wisdom which presided over their formation? Or who can regard with indifference the sciences which have substituted for the narrow, insignificant world of the ancients, our magnificent solar system, and so extended our starry vault that we cannot attempt to fathom its depths without a feeling of religious awe? Certainly a knowledge of the marvelous laws which govern the universe gives a much grander idea of the power of the Divinity than that which blind superstition would impose upon us. If the material pride of man is humbled by the thought of the small space he occupies even upon the grain of dust he calls his world, how much he should rejoice in his intelligence, which allows him to penetrate so far into the secrets of the heavens. If science has advanced thus in the study of worlds, may we not look for equal progress in the study of man? Is it not absurd to suppose that, while all else is controlled by admirable laws, the human race alone is abandoned to blind chance, and possesses no principle of conservation? Such a belief is surely more injurious to the Divinity than the research we propose.

In 1832–'33 appeared an article "*Upon the possibility of measuring the influence of the causes which modify social elements*," and one "*Upon the influence of the seasons upon the faculties of man.*" As soon as Quetelet obtained a new result he hastened to make it known, often before his idea was sufficiently matured or the fact at all certain, which accounts for the repetition in his articles. This mode of working has some advantages; it excites interest and parallel efforts, but it occasions loss of time, and renders the co-ordination of the researches more difficult. In 1835 appeared the admirable work, "*Man and the development of his faculties;*" or, "*An essay upon social physics.*" It is a review of all his previous works on statistics; "a sketch," he calls it, "of a vast picture, the details of which can only be supplied by patient investigation." It is divided into four volumes: the first two are devoted to the physical qualities of man, the third to his moral and intellectual qualities, and the fourth treats of the properties of the average man, and of the social system. The author considers, first, the determination of the average man in general; second, with respect to physical qualities. He then proceeds to examine all that relates to the life of man; his birth, death, strength, height, agility, &c. We give some extracts: "The appreciation of the physical qualities of the average man is by no means difficult, either when measured directly or through their effects; it is quite otherwise with the moral and intellectual qualities, though they also, to some extent, may be judged of through the effects they produce." "Man possesses at his birth the germ of all the qualities which are successively developed, to a greater or less degree; prudence predominates in one, imagination in another, avarice in a third. We sometimes observe great size in proportion to age, or a precocious imagination, or unusual vigor in old age, and the fact alone that we notice these exceptional cases proves that we are conscious of a general law of development, and even make use of it to form our judgment." The author successively considers the average man, first, with reference to letters and the fine arts; second, in relation to the medical or natural sciences. "The consideration of the average man," he says, "is so important in medical science that it is almost impossible to judge of the condition of an individual without comparing it with that of a fictitious being, supposed to be in the normal state; in fact, the average man we have been considering." Third, in relation to philosophy and morals; and, fourth, in relation to politics. It is quite curious to see how he regards political systems. He is opposed to the system which consists, when there are two dominant ideas in a country, in taking a kind of mean between the two, but would found a system upon the elements common to all parties; or, where there was divergence, upon the ideas held by the largest number. "Governments," he says, "have their states of equilibrium, which may be either stable or unstable. The stable equilibrium exists when, after action and reaction of every kind, a government constantly returns to its normal condition. If, on the contrary, from any cause whatever, a government tends to diverge more and more from its normal condition, changing constantly, without sufficient motive, its form and institutions, its end is near. Revolutions are only the reactions of the people, or a party, against abuses, real or supposed, and would not take place if the provocation did not exist. The liberty of the press, singularly enough, by facilitating these reactions, renders great revolutions almost impossible, for it does not allow forces to accumulate. The reaction is manifested immediately after the action, sometimes almost before the action has time to propagate itself." This essay gave its author a high place in the scientific world. It was translated into both English and German. We have not space to notice other papers upon statistics, which appeared in 1845-'46-'48. He was happy in his application of mathematics to statistical questions. He formulated the now well-known *binomial* theorem, and insisted, more especially in his last years, on its remarkable generality. He organized the first statistical congress, which was held in Brussels in 1853; and was appointed its president. He was also president of the commission of statistics of the kingdom of Belgium. On account of his works on social statistics he was made, in 1872, an associate of the section of moral and political sciences of the Institute of France. He had long been a corresponding member of this academy.

He was a member of the Royal Academy of Belgium, as we have said, from 1820, and held the presidency of this learned body from 1832 to 1835, and then succeeded M. Dewez as perpetual secretary of its three divisions, science, literature, and the fine arts. We have been able to notice only a few of the memoirs inserted in the publications of the academy. The bulletins of each *séance* are, so to speak, crowded with his articles. One can see, by their inspection, with what care he registered all the remarkable phenomena which presented themselves during his long career. Thanks especially to him, they, as well as the *Annuaires* and *Annales* of the Observatory, will always be consulted with profit by those who wish closely to study the aurora borealis, shooting-stars, bolides, storms, earthquakes, and such phenomena, upon which attention is drawn so strongly at the present time, and of which, for the most part, a complete theory has not yet been formed. The correspondence which Quetelet had with the official heads of science in different countries contributed greatly to extend the relations of the academy, and to enrich its bulletins.

The revolution of 1848 was not a surprise to Quetelet; he foresaw that the opposition of Louis Philippe to reforms, not in themselves to be feared, would cause some such catastrophe, but he did not anticipate the effect it would produce all over Europe. His attention, of course, at such a time was turned to politics, and in the month of March he presented to the academy a paper upon the nature of constitutional states, and some principles which may be derived from the consideration of them. Several other articles were also written by him on political subjects. We know that while other governments were falling, Belgium remained intact, and while distress and terror were reigning elsewhere, she prepared to celebrate the anniversary of her independence. The *fête* in honor of the occasion was organized by Quetelet as head of the artistic and literary circle, and never was a more brilliant entertainment given in Brussels. It evinced not only the good taste of Quetelet, but the extent of his influence.

As to the private life of Quetelet, we have said that in 1825 he married Mademoiselle Crulet, niece of Professor Van Mons. Two children, a boy and a girl, were the fruit of this union. His mother and a young half-sister, who married an artist, M. Madou, formed the rest of his household. The children were educated at home. Madame Quetelet herself taught them to read, and they had a master for writing. Every Sunday a few friends were invited to dinner, and in the evening the house was open to visitors. There were conversation, music, and charades. The latter were in great favor, and Quetelet himself often took part in them. Those who knew Quetelet only through his works, or when enfeebled by age and disease, can have no idea of his gayety, wit, and cordiality. He thoroughly enjoyed a laugh, and Rabelais was almost as much of a favorite with him as Pascal. His conversation was admirable, bright, merry, witty, condescending to the most trivial as well as embracing the most extended subjects in letters, science, and art. It was marked occasionally by a vein of severity, which, however, never wounded any one, and only served to bring into stronger relief the amiable traits of his character. He possessed the very rare faculty of knowing when to listen, and always managed to make his guests feel at ease. As the years passed, he attained more and more a position of distinction. The husband of his sister became a painter of eminence; his daughter married a promising young artist, and his son, one of the best pupils of the military school, quitted the engineer corps of the army, when he had attained the rank of lieutenant, to enter the observatory. Death soon deprived him of his mother, whom he loved tenderly, but his wife remained his companion for thirty years.

In the last years of his life, when his age warned him in vain to take repose, he undertook a series of works which he intended to be an epitome of the labor of his life. In 1864 appeared "*The History of Mathematical and Physical Science in Belgium;*" in 1866, "*Mathematical and Physical Science in Belgium, from the Commencement of the Nineteenth Century;*" in 1867, "*The Meteorology of Belgium, compared with that of the World;*" in 1869, "*Social Physics, or an Essay upon the Development of the Faculties of Man;*" in 1870, "*Anthropometry, or Measure of the Faculties of Man.*" If death had not overtaken him he would have completed the series by a new edition of his "*Physics of the Globe,*" published in 1861, and by a treatise on astronomy.

We will not attempt to enumerate the learned societies of which Quetelet was a member; the list would be too long. He was elected an associate of the Royal Astronomical Society on January 11, 1828.

Notwithstanding the numerous occupations which claimed every moment of his time, Quetelet always gave the kindest reception to those who wished to speak with him on subjects connected with his studies. He could discern and would encourage merit, and many learned men will remember the support they received from him, in the commencement of their career, with feelings of profound gratitude.

Eighteen months before his death he undertook the fatiguing journey to St. Petersburg, at the pressing invitation of the Grand Duke Constantine, under whose auspices the statistical congress had been called. Neither the fear of cholera nor the entreaties of his friends deterred him. He was much gratified by the reception given him, and appeared to have been benefited in health by the journey. On Monday, the 2d of February, he fulfilled exactly his duties as secretary of the academy, although suffering from the disease of the lungs of which he died fifteen days later. And he also assisted at the session of the class of letters. He died on the 17th of February, 1874, and Belgium deplored her greatest scientific luminary. The "academy" was the last word on his lips as he sank into unconsciousness.

EULOGY ON ARTHUR AUGUSTE DE LA RIVE.

BY M. DUMAS, *Permanent Secretary.*

Pronounced before the Academy of Sciences of the French Institute on the 28th of December, 1874.

GENTLEMEN: One year ago the Academy of Sciences received with profound sorrow the unexpected announcement of the death of one of its eight foreign associates, M. Auguste De La Rive. The rare talents of this eminent physicist, his warm heart, and high moral character, won for him in his native city universal affection. Geneva mourned for him with deep and sincere regret, for she lost in him an eminent philosopher and professor, who added to the renown of her justly-celebrated academy; a citizen whose loyalty had frequently been tested in times of trouble; and a useful member of society, whose generous hospitality delighted in gathering around his fireside representatives of the science, art, letters, and politics of all nations.

But Geneva was not alone in her grief. The services of M. Auguste De La Rive were such as the whole world recognizes, and of which posterity cherishes the memory. France, at least, cannot forget that if in time of prosperity she found in him always a faithful and provident friend, whose solicitude for her reputation seemed sometimes almost chimerical, she was none the less sure of his active sympathy in days of misfortune. When Switzerland opened her heart to our soldiers, who, betrayed by fortune and decimated by the sword, cold and hunger, had retreated to the snows of the Jura, Auguste De La Rive and his associates brought to them succor and consolation; not unmindful that our two races, united by an old friendship, had often mingled their blood under the same flag.

It was not only to the illustrious physicist that his native city rendered the homage in which we this day unite. To the happy gifts bestowed by nature was added the prestige of an ancient and honorable name. The family of De La Rive may be traced back to Ripa de Mondovi, and is, in fact, one of those in which is personified the history of Geneva. From the twelfth century, for more than four hundred years, it is found in the first rank of the government archives of the city; from the fourteenth century, it includes a judge of Piedmont; a lieutenant of police, opposed to the Reformation, and exiled from Geneva for having advocated in secret the Catholic religion; a plenipotentiary, charged with demanding of Henry IV, in favor of the Genevese, certain privileges which were only granted by royal patents; an envoy of the canton, sent to Louis XIV, when asylum was given by the small republic to the refugees who had been driven out of France by the revocation of the edict of Nantes; and, in the last century, three generals, one in the service of the Turks, another in Holland, and a third in Sardinia. Up to this time there is no appearance of a scientific tendency among the members of this family, so rich in every other line of personal distinction, probably because the public mind was not turned in that direction; but toward the end of the last century, we see them attaining in science the same high position they held in public affairs. The mother of the illustrious historian of the Alps, De Saussure, belonged to the family of La Rive, and also the wife of the learned philosopher, Charles Bonnet; both of whom, tradition says, exercised great influence, the one over her son, the other over her husband. In fact, the history of the family from the beginning of the present century would give not only that of the country, but also the most interesting chapters in contemporary science.

Charles Gaspard De La Rive, father of our lamented associate, was the first savant of the name. His works form, with those of his son, an indivisible whole. Destined for the magistracy, he pursued his law-studies until, in 1794, Geneva suffered a deplorable repetition of the French revolution. He took an active part in resisting the insurgents, and was imprisoned and condemned to death by the revolutionary tribunal. Thanks to the exertions of his friends, he escaped, took refuge in England, and went to Edinburgh to study medicine. His mother was very much opposed to his adopting this profession, as she considered it beneath the dignity of the family. She refused to pardon him for pursuing a course contrary to her wishes, and, as she forbade his return to his native land, he remained in exile long after the decree of amnesty allowed his appearance in Geneva. That he should have regarded such an unjust prohibition, caused by what seems to us a strange and unreasonable prejudice against an honorable profession, is very remarkable; but it must be remembered that in Geneva, at that time, aristocratic feelings largely prevailed, and public and private education, in spite of Rousseau, was based upon the inculcation of entire submission on the part of a child to the absolute authority of the parent.

On his return to his country, Gaspard De La Rive devoted himself with diligence to such studies as were necessary to fit him for the chair of chemistry, and through the liberal character of his mind, which was open to the widest generalizations of science, was led to the investigation of the electrical forces, to take part in the grand reform in natural philosophy then occupying the attention of France, and to lay the foundation for the future course of his illustrious son. If, in the history of science, the De La Rives may not be placed in exactly the same rank as Oersted, Ampère, Arago, and Faraday, whose labors they shared, certainly they cannot be widely separated from them. The united efforts of this brilliant pleiad of physicists, which includes M. Becquerel as a later and none the less distinguished representative, have added to civilization a knowledge of forces which are now indispensable to industry and commerce, and of which, alas, the fury of war has increased the importance. How the applications of these agents, the discoveries of peace-loving men, have been perverted! How the rapid telegram from the cabinet of the statesman inflames at will the passions of the people! How electricity, at the command of a distant engineer, explodes the torpedo which violently disturbs the sea, or fires the mine which rends the earth like a volcano, extending on every side devastation and death!

Gaspard De La Rive was a successful expounder of chemistry, and taught its principles with clearness and simplicity. His numerous and choice experiments rendered his instruction interesting and valuable not only to the students who desired merely a theoretical knowledge of the subject, but also to the industrial classes, who sought to make practical application of the information obtained. He proposed to make chemistry a part of the curriculum of a liberal education, and he succeeded in attracting, by the eclat of his experiments, students of all classes, whom he afterward retained by directing their minds from these lower objects to the beauty and precision of the higher conceptions of natural philosophy. No one contributed more to popularizing the atomic theory of Dalton, which he considered a most happy hypothesis. Having studied in England, he retained a taste for large apparatus, in which his fortune allowed him to indulge; his voltaic batteries were without a rival on the continent. But while his laboratory was English, the constitution of his mind, on the contrary, led him to adopt the ideas of Lavoisier and the doctrines of the French Academy.

His countryman and friend, Dr. Marcet, a chemist of distinction, living in London, came to pass a winter in Switzerland. He could not endure this preference for the school of Paris, and endeavored to convert the select audience Gaspard De La Rive collected about him to the ideas of the London school, especially to those of Davy, whose renown at that time was world-wide. The pupils of the chemical course had, therefore, the singular good fortune of having two professors, each of whom discoursed in turn upon the same subject, explaining the views to which he gave the preference. The two teachers, stimulated by opposition, gradually advanced from the ordinary conventional and classic grounds of instruction to heights where definite thought commences to waver into nebulous speculation. These lectures, which amounted to academic sessions, awakened the curiosity and excited the enthusiasm of the audience, who, while divided in opinion, were always united in praise of the ardor and mental activity of the two friends.

Gaspard De La Rive was affable, benevolent, paternal, and good-humored. His joy in the success of a well-conducted experiment, his satisfaction when he felt himself understood, was indicated in every lineament of his expressive countenance; and, after listening to the good man, his auditors were surprised to find that, although his discourse had been entirely of chemistry, they felt themselves better, as well as knew themselves wiser, from the sympathy awakened by the glow of his lecture. Besides, no one could be indifferent to the moral example displayed by this, the first syndic, the chief of state, the possessor of a large patrimonial fortune, who was thus laborious in the discharge of a daily duty, without other motive than the love of science—for no other recompense than the respect accorded to noble and unselfish conduct. Those favorites of fortune who pass their days in the pursuit of idle pleasure, have no idea of the rational enjoyment to be derived from the pursuit of knowledge or the disinterested instruction of youth. Were an entire aristocracy similarly disposed, leading its followers through the learning of ancient times and the science of the present, what conquests would be made in the domains of intelligence; conquests which would necessitate no violation of right nor infliction of wrong, would bring loss or distress to none, but benefit to all.

During the long wars of the revolution and of the empire, Geneva rendered great service to the scientific world by the publication of a review which her extended commercial relations and the cosmopolitan habits of her people supplied with abundant information upon all subjects, and which was edited by a distinguished physicist, M. Pictet, under the title *Bibliotheque Britannique.* It was by means of this periodical that the works of the English scientists became known over the continent; and through the personal influence of the eminent men who assisted in its compilation, it retained long after peace was established the monopoly of the earliest foreign intelligence. In its pages Arago, who was on a visit to Geneva, in 1820, first learned of the great discovery of Oersted, the action exerted by the electric current of the voltaic pile upon the magnetic needle. At that time it was known that two substances could act upon each other, combining and producing changes in their properties, exhibiting phenomena which constitute an essential part of chemistry, but no one had ever seen what was then called an imponderable fluid act upon another. Light produced no effect upon heat, and neither acted upon electricity. Oersted, however, announced that electricity could be made to act upon magnetism. A new science, with the most remarkable practical applications, of which the electric telegraph is only one example, was developed from this fruitful germ. All who assisted in establishing the genuineness of this wonderful discovery were greatly impressed by it, and no one felt inclined to contradict the grave comment of Pierre Prévost, the author of the theory of the unstable equilibrium of radiant heat: *Novus rerum nascitur ordo.*

Arago, on his return to Paris, thus speaks of the event: "Professor De La Rive, of Geneva, who has himself discovered many curious phenomena with the powerful battery in his possession, allowed me to witness his verification of the experiments of M. Oersted before MM. Prévost, Pictet, Th. de Saussure, Marcet, de Candolle, &c., and I was entirely convinced of the accuracy of the principal facts stated by the Danish philosopher." I am, I believe, the sole survivor of this historical scene, in which I took part as one of the *et cætera* of Arago, and I shall never forget the powerful impression produced upon those who were present. Nearly all came with the conviction that Oersted was the dupe of some illusion; but they saw the magnetic needle obey the action of the electric current, move in one direction when the conducting-wire of the battery was placed above it, and in the contrary direction when placed below it, and were convinced that these effects could be attributed to no external agitation, since they were produced in the vacuum of the air-pump, as well as in the open air, and ceased when a slip of wood was substituted for the magnetic needle.

Ampère, in Paris, entered upon the investigation of this phenomenon with great enthusiasm, and having, by dint of earnest and persevering thought, arrived at general conceptions, he deduced from these inferences, which he immediately proceeded to verify by actual experiments, employing for the purpose all the resources of practical mechanics. The discoveries that followed week after week in rapid succession excited the unbounded admiration of Gaspard De La Rive, and no sooner had the Academy of Sciences of Paris announced some new inference of Ampère than the watch-making establishments of Geneva, under the direction of De La Rive, constructed the delicate apparatus conceived by the illustrious French physicist to verify his deductions, and varied the form so as to bring it within the means of the smallest laboratory.

If in this De La Rive was animated solely by a love of science, he was amply rewarded.

Auguste De La Rive, excited first by sympathy with his father, and afterward by individual interest in the new facts brought to light, determined to devote his life to the study of electricity. Born on the 9th of October, 1801, he was at the time of these researches a student in the university, but shortly after prepared resolutely and with success to compete for the chair of general physics left vacant by Pierre Prévost. Only twenty-one years of age, and aspiring to take the place of a professor well known throughout Europe, he was obliged to face a jury composed of sixty-six judges, that is to say, of all the professors of the academy, and all the members of the venerable company intrusted with the direction of the ecclesiastical affairs of Geneva. The academy was at that time a powerful corporation. Closely united with the church, it was considered the first educational establishment, and held control over all the other schools of the canton. It constituted a state within the state, and extended its jurisdiction even to politics and the affairs of the republic. The authority with which it was invested was founded upon traditional laws, and its functions were highly respected. Its professors, select men, were all capable of serious work and prolonged application. Very poorly remunerated for their services, their expenses far exceeded their emoluments, but they valued the prestige of a professorship, a truly magisterial office, much more than its material profits. The high character of the political instruction attracted to the academy the rich and noble families of the country, and the taste for letters and science it promoted, with the habit of devotion to their culture, was transmitted from generation to generation, enabling the school of Geneva to maintain a high position among the most renowned universities of Europe. It was a source of intellectual activity, and a center of light, such as is supported only by great effort in countries of much larger extent than Switzerland.

As soon as the discovery of Oersted was announced, Ampère offered the following explanation: The frictional electricity, or that developed by rubbing glass, long known, is a fluid in repose, and constitutes statical electricity. The electricity of the voltaic pile is this same fluid in motion in the direction of the axis of the conductors, and this is dynamical electricity. Again, this same fluid circulating around the molecules of a bar of iron or steel, in a plane perpendicular to the axis which united the two extremities, is magnetism. To give a material illustration of these forces, the water which moistens the surface of a solid body may represent statical electricity, the water which flows through an aqueduct dynamical electricity, and that which passes in the turns of an Archimedian screw, magnetism.

On the 4th of September, 1820, Arago announced to the French Academy the facts whose confirmation he had witnessed at Geneva, and on the 25th of the same month Ampère read his valuable memoir, which alone would have given his name one of the highest places in the history of science. His theory of the principles of electro-magnetism was founded upon his fundamental experiment that two voltaic currents in the same direction attract each other, and, on the contrary, repel each other when they are in opposite directions—a phenomenon he had foreseen and predicted as a result of his *a priori* conception. To this striking proof of the truth of his theory he soon added another. He imitated a magnet by passing a voltaic current through a metal wire coiled into a spiral, and suspended freely in a vertical plane. This spiral was affected by the action of the earth like the magnetic needle, which Ampère explained by supposing that the lower parts of the wire, that is, those nearest the earth, controlled the whole. This experiment was also exhibited in its simplest form by suspending a rectangular wire so that it could move freely. When a voltaic current was passed through this, it arranged itself at right angles to the direction of the magnetic needle. Now Gaspard De La Rive removed the lower horizontal part, and the remainder of the wire was as much affected by the terrestrial influence as when the rectangle was complete.

The explanation of Ampère was thus shown to be incorrect, and his theory for a time lost its best support. His state of mind under the influence of this disappointment bordered on derangement. When alone, he passed hour after hour in profound meditation; and when with his family, pursued the avocations of life in a sort of somnambulism, oblivious of everything around him. At length, however, in a moment of inspiration, the truth dawned upon him, and delivered him from this state of distraction. He caught sight of the proper solution of the problem, and in the experimental verification of this, Auguste De La Rive came to his aid, and by his ready invention reduced the phenomenon to its simplest elements. He removed one by one the sides of the rectangle, and reduced it at last to a single vertical wire, freely suspended, which, when the voltaic current passed through it, was as sensible to the action of the earth as the entire rectangle. These delicate experiments so interested Ampère that he came from Paris to Présinge, the country residence of De La Rive, to witness them, and to perfect the explanation to which he had given so much thought.

The memoir of the young physicist on the subject contains not only the new results he had obtained, but also the learned and decisive formula by which Ampère connected them with his theory, now complete and triumphant.

Thus in the very commencement of his career the name of Auguste De La Rive was associated with one of the most interesting episodes in the development of the theory of Ampère, and his first investigations placed him at once in the focus to which all the intelligence of the age was directed. They not only brought him into relation with Ampère, but prepared the way for the life-long friendship which afterward united him with Faraday, who already, grateful to his father for early recognition and encouragement under peculiar circumstances, was predisposed to regard him with favor. When Davy was making his admirable investigations in regard to the voltaic battery, Great Britain and France were engaged in a desperate contest. The first class of the Institute, however, considering the field of science and the pursuit of truth above the prejudices occasioned by national quarrels, awarded to the English philosopher the prize offered in the department of electricity by Napoleon. Although the countries were then at open war, Davy shortly after received permission to visit Auvergne, in order to study the extinct volcanoes of that province, and was also allowed to go to Italy and continue his researches on volcanoes in action. In this courteous exception, France set an example eminently worthy to be followed by all civilized nations. The passport Davy received included himself, his wife, and one servant. Faraday, eager to acquire knowledge, did not hesitate to accept the latter position. The young savant was unobserved in his new capacity while in Paris, as he did not speak a word of French, but it was quite otherwise at Présinge, where Davy remained some time. Gaspard De La Rive, observing his isolation, addressed some kind words to him during a hunting excursion. Discovering immediately that he was by no means an ordinary servant, an explanation followed, and he was requested to take the place in the family, at the table of his host, which his true position and talent deserved. Davy, however, while he did not object to this arrangement when he was absent, insisted that in his presence the subordinate position assumed should be maintained. This simple incident might have made but little impression upon Faraday, had it not brought into strong contrast the pride of Davy and the affable cordiality of Gaspard De La Rive.

Even genius does not excuse pride or pardon exclusiveness. Davy, satiated with praise and loaded with honors, but lacking the sympathy of his countrymen, passed the last years of his life on the continent, and came to Geneva, to terminate sorrowfully, in a foreign country, his days of lassitude and *ennui;* while, on the other hand, when Faraday, endowed with the modesty which charms and the kindness which attracts, approached his end, the savants of the entire world evinced their affection for him; the most eminent personages of England testified their respect; his death was a source of universal regret, and his memory, cherished in all hearts, is still honored at the Royal Institution of London, in the amphitheater, the scene of his triumphs, by an annual and imposing ceremony presided over by the Prince of Wales. What a contrast is this!

As the scientific career of Gaspard De La Rive ended and that of his son commenced, a new era commenced, fraught with ideas to enlighten, agitate, and even trouble the world. The father had witnessed only the prelude to the great changes which were to take place, but welcomed with joy the new dawn. The son, after laboring with ardor and success in the unveiling of truth, at the close of his life contemplated, with sadness as well as pleasure, the unexpected consequences of the discoveries in which he had taken an active part.

A half a century ago science, although full of promise to those who sought to penetrate its mysteries, did not appeal to the common mind. Its language was little understood even by those who held the destinies of nations in their hands. Its demonstrations and discoveries were regarded by the public with a careless eye and considered of no importance. Soon, however, under its influence, rapid vessels, impelled by steam, traversed the sea; railroads crossed the continents; thought circulated from one hemisphere to another through the electric telegraph; the beet-root of the frozen regions rivaled the sugar-cane of the south; gas lighted the streets; fossil remains fertilized arid ground, and the colors from coal-oil vied with the fresh tints of the flowers; while the sailing-vessels lying idle in the ports, the forsaken stage-coach, the deserted roads, the laborer deprived of employment, were other but equally forcible witnesses to the irresistible power of the practical application of the principles which govern the universe. At the same time iron and steel were perfected and produced in abundance; powder and other fulminating substances were rendered manageable; rude and inefficient weapons of war were converted into large and powerful engines of destruction; and in view of houses in ruins, crops destroyed, and the multiplied graves of the dead, it was impossible longer to question the importance of those investigations and discoveries which had once been despised.

Again, a new conception of the universe, based upon the existence of atoms, the latest representatives of matter, and upon the vibrations of the ethereal medium, the latest symbols of force, induced a certain school to revive doctrines which, originating in Greece, were translated by Lucretius into harmonious verse in order to convert the voluptuous aristocracy of Rome to the philosophy of Epicurus. The Latin poet exclaims in his antique materialism, "He wakes not again who sleeps with the dead; we are only the temporary proprietors of life and not its owners. When the body perishes, the soul also is decomposed; it dissolves as the limbs crumble into dust. The soul dies entirely with the body, and in vain might the earth be mingled with the sea, and the sea with the sky, in one frightful tumult—nothing can ever awaken it."

Modern materialism, content with reviving the doctrines of Epicurus and Lucretius, considers the world as the fortuitous production of the arrangement of atoms; man as the highest development of the natural evolution of organic forms; life as a spontaneous modification of force; birth as the commencement of a phenomenon, death as its end. When, in the light of this philosophy, justice is only a social convention, conscience the fruit of education; charity, friendship, love, only varied forms of selfishness, those intrusted with the care of human souls should acknowledge the terrible power of this contemned science.

The scientific conceptions of the human mind, of great importance as expressions of generalizations, are the result of ideas derived from our present understanding of the phenomena of matter and force, but cannot be considered as absolute truths. Lavoisier, studying chemical actions, the balance in hand, proved, it is true, that in each of these, the weight of the substances produced is equal to that of the substances employed. Let us accept, then, this discovery as a philosophical truth: that matter has weight; that man has never created nor destroyed anything that has weight; in nature, since the universe received its present form, nothing has been lost, nothing created that has weight; matter changes its place, its aspect, and condition, but it does not perish. Is it the same in regard to force? While always remaining imponderable, will it also be variable in its manifestations, perpetual in its activity? Man powerless to create matter, is he equally unable to produce force? Auguste De La Rive has largely assisted in proving that this is the case, and, in so doing, has traced to its highest philosophical consequences one of the most humble experiments of the laboratory, that of Galvani. Two plates, one of zinc the other of copper, produce a sensation when an organ is touched with their two free extremities; the tongue is sensible of a taste; the eye perceives a light; the ear is conscious of sound. By increasing the number of these metallic couples, extending their surface, and plunging them into a saline or acid liquid, Volta constructed his celebrated battery, by which he produced light and heat comparable with those of the sun, a chemical power superior to that of the volcano, a magnetism equal to that of the earth, and physiological phenomena previously considered as belonging only to manifestations of life. Can it be supposed that all these forces spring from nothing, and that the two metals which produce them remain unchanged in their nature, weight, and other qualities?

German science, still involved in the obscurities of the philosophy of nature, was of this opinion, notwithstanding the experiments of M. Becquerel, sr. Auguste De La Rive thought otherwise; he did not so readily accord to man the faculty of deriving, from nothing, either matter or motion. His mind revolted against such an assumption. He proved, in fact, that no electricity was manifested if one of the two metals was not oxidized; that is to say, if it had not undergone chemical change. The electric current is slight when the chemical action is feeble; intense when it is powerful. The electric circuit starts from the metal attacked and passes over to the other. If both metals are affected at once, the electric circuit begins in the one in which the chemical action is strongest. Change the nature of the medium, and you may reverse at will the action and consequently the direction of the current. The latter experiment is decisive. If the contact of two different metals is sufficient to create the electric current, this ought always to proceed in the same direction. If this current is the result of chemical action, it should, on the contrary, move sometimes in one direction, sometimes in the other, starting from the metal attacked and proceeding toward the one not affected, as was proved by Auguste De La Rive. If we measure the electricity obtained, we ought also to note the chemical force expended. We create nothing; we only transform. Such is the theory of the pile. Faraday devoted much time to the consideration of these truths, but we can do honor to the Genevese physicist while acknowledging our indebtedness to the great English philphilosopher.

If the burning of the coal develops the force of the steam-engine, the zinc consumed produces the power of the Voltaic pile. The battery no more creates the electricity that it utilizes than Watt's engine produces the heat that it employs; that electricity comes entirely from the metal burned by the acids. Pursuing this idea, Auguste De La Rive measured the heat which was manifested in the different elements of a battery, in full activity, and found that it did not exceed that produced by the chemical action exerted upon the metal attacked—a conclusion confirmed by the learned dean of the faculty of Marseilles. It is, then, evident that man creates neither electricity, magnetism, heat, nor light; he draws these forces from the reservoirs in which they are hidden and in which they were stored without his aid.

We insist that in nature, as she appears to us, nothing is lost, and nothing is created of that which has weight; we dispose of matter as we choose in order to produce chemical combinations *ad infinitum;*

forces are only the causes of movements, which we transform, one into the other at will. Well, is this to say that the world has no other sovereign than man, and that he rules as master? Let us see if this is so.

Newton considered light, heat, electricity, and magnetism as so many distinct imponderable fluids. This opinion served as a guide to all the investigations of the eighteenth century and of the commencement of the nineteenth. It was the expression of the truth of the time—was, so to say, the fashion—and it had its fanatical followers, in the first rank of whom was Voltaire. It is now superseded by a theory indicated by Descartes and Huyghens, and which Newton undertook to develop, but abandoned, perhaps because of the difficulties it offered to calculation. This supposes the existence throughout the universe of an elastic, ethereal medium, that is to say, an exceedingly subtile substance, in which float the atoms of ponderable matter. Acting one upon the other, or through internal agitation, these atoms determine, in the ether by which they are surrounded and penetrated, undulations more or less extended, more or less rapid. These vibrations of the ethereal medium constitute light and heat, while electricity and magnetism are the manifestations of the medium itself. Ponderable atoms, an elastic ethereal medium, and the vibrations produced in the latter by the atoms; such is the present conception of the universe. It is simple, true, perhaps, said Auguste De La Rive, but who knows what will be thought of it a hundred years from now? How is it possible to believe that after remaining in ignorance and error in regard to these great subjects from the commencement of the world, man, in less than a century, could acquire complete knowledge of all that concerns them and leave nothing to be discovered by future ages? It behooves us to be more modest, lest our descendants laugh at our audacity.

Among all the different manifestations of the ethereal medium, electricity is the most constant, not only in the reactions of inanimate bodies, but also in the material phenomena we observe in living organisms. It was hastily inferred by some that electricity was life, but Auguste De La Rive would not admit that life could result from this unconscious action of atoms upon ether. He had never seen it manifested spontaneously, and believed that since its first appearance upon earth it had constantly been transmitted from parent to offspring. He considered, moreover, that human personality does not exist in the dust of which our bodies are composed. Is matter that obeys eternal, and the spirit which commands perishable? I would rather, he says, believe that the intelligent soul is immortal and brute matter perishable. He believed the world to have been created and demonstrated as a fact of a scientific order, and, by arguments that M. Clausius afterward developed, that it had not always existed; that it had a beginning, and would have an end.

Ampère, Faraday, and Auguste De La Rive made electricity the subject of profound study, and it was the instrument of their greatest discoveries. They were all three very religious, and delighted in meditating upon subjects of a metaphysical character. The first sought to explain universal attraction by magnetism; the second denied even the existence of matter, and considered each atom as a center of force whose vibrations are felt throughout the universe; they endeavored to defend, against the encroachments of the partisans of physical forces the domain of the spirit, that something which thinks, affirms, denies, wills, imagines, feels, and which, free to follow its inclinations, should render an account of its liberty. They were convinced that by such meditations the soul approached the supreme power, whose direct intervention appears like a continued creation.

Belonging to the same school of philosophy, they enjoyed discussing together such questions as the following: Attraction, which sustains the stars in space, who knows its nature? Affinity, which connects the molecules of bodies, is it not a word whose sense escapes us? We represent matter as composed of atoms; are we sure that these atoms exist? The physiologist describes the phenomena of life; does he know in what life consists? The geologist, who writes the history of the globe of which he has only penetrated the epidermis, does he know its origin and end? If man is proud of the knowledge he has acquired, should he not be humble in view of what he has yet to learn?

The publications of our associate are numerous, and attest the activity of his mind as well as the extent and accuracy of his information. But an eminent physicist, M. Soret, is preparing a complete history of them in his native land, and in this article I can only notice a few of their principal features, and, in particular, his beautiful theory of the aurora borealis.

The chronicle of Louis XI reports that, on the 23d of July, 1461, a meteor appeared "of such color and brilliancy that it seemed as if all Paris was in flames;" it adds, in consternation, "May God preserve us!" On the 18th of November, 1465, a similar appearance produced like terror. The king, Louis XI, mounted his horse and rushed to the walls, and the city guard were assembled and posted. The country at that time was in revolt against the government, and it was supposed that the enemy before Paris were attempting to fire the city.

We ourselves witnessed a similar excitement, caused by the appearance of the aurora, during the siege of Paris by the Prussian army. From the beginning of the night until the first actual appearance of the phenomenon, a glow was observed in the north, which gradually deepened into a rose-tint, and spread over half the sky. From time to time colored rays shot forth, of a deep blood-red, while spots of the same sanguinary hue appeared here and there above the city. When the phenomenon had reached its height, and the sky commenced to darken, suddenly the red color shone out again with frightful brilliancy. The next evening the appearance was repeated with somewhat less intensity, but accompanied by luminous white radiations toward a center near the constellation Pegasus. The inhabitants of Paris were greatly alarmed. They supposed that some great incendiary machine had been put in play, to force the walls or demoralize their defenders. A few of them, seeing that it was a remarkable example of the aurora borealis, sought in it such omens, happy or otherwise, as their excited patriotism suggested.

The Aurora of the North, as Gregory of Tours called it thirteen hundred years ago, varies somewhat in aspect with the latitude. In the polar regions it is so common that it ceases to excite remark, and is often confounded with the twilight. In the center of Europe it is less frequent, and almost always characterized by the deep bloody hue of the sky, and the rays that dart like lances across it. Its appearance justifies the description that it seems as if two great armies, enveloped in fiery vapor, were engaged in mortal combat. In Calabria, where it is still more rare, the imagination finds in it arcades and porticoes, while Greece, always poetical, and very seldom honored by this celestial visitation, sees in the illuminated sky the assembly of the gods in council upon Olympus in the presence of Jupiter.

How are we to account for these appearances? Auguste De La Rive considered that they were produced by electrical conflicts, silent and mysterious, converging toward the magnetic pole of the earth. Every one is familiar with the electric light, whose power is exhibited in the light-house, on the stage, and in public illuminations. This brilliant phenomenon, discovered by Davy, was especially noticed by Arago, who declared, *a priori*, that it would offer the then strange spectacle of a flame obeying the action of a magnetic bar. Experiment confirmed his prediction. When this luminous arch is approached by the poles of a strong magnet, it is attracted or repulsed; its curvature increases, the brilliancy of the flame diminishes; it is varied by jerks and by flashes of colored light when silk is rubbed near it, and the arch at last breaks, when the curvature is so great that it extends too much the surface passed over by the electrical discharge. A magnetic needle placed in the vicinity manifests, by its incessant agitation, that it is affected by a strong magnetic influence. Is not this the image of the aurora polaris?

Arago devoted many years to the study of the influence of the aurora borealis upon the magnetic needle; and often announced the appearance of the phenomenon in the north of Europe, even before it was manifested in France. He was too cautious, however, to hazard an opinion in regard to its nature. Auguste De La Rive took up the subject—we should rather say, devoted himself to it—and among the many reasons for regretting the death of this illustrious savant is the loss to science of a work he was preparing upon the polar lights, the materials for which he had spared no pains in collecting. The apparatus is well known, at least in the lecture-room, by means of which he reproduced the fundamental conditions of the phenomenon, which he considered due to the formation of a luminous ring in the upper regions of the atmosphere, having for center the magnetic pole. By transmitting through a rarified gas an electrical discharge around the pole of a strong magnet, he caused a luminous ring to appear, animated with a movement of rotation around this same pole. This experiment is so beautiful that it must be admired even by those physicists, now few in number, who consider that the aurora is derived from a source far beyond the terrestrial atmosphere, and attribute to it a cosmical origin. He writes thus to me, only a short time before the attack of illness which caused his death: "Assist me in defending a theory, which I believe to be founded upon incontestable facts, and which was advocated by Franklin and Arago when there was less evidence in its favor. The investigators who study only the brilliant and occasional auroras of our latitudes, should also take into consideration those less radiant that appear almost every day in the polar regions. I do not know a single observer, placed in our extreme northern countries, who does not support the views I have adopted. Surely it is much in their favor that they are advocated by men who live in the midst of the phenomena; and shall we abandon them because they are opposed by those who witness these remarkable appearances only occasionally, and under the influence of surprise and astonishment which must more or less affect the judgment concerning them?"

At the equator, the silent magnetic agitations are replaced by electrical storms, accompanied by thunder and rain, marking, so to say, the course of the sun; and if there is a constant manifestation of auroral phenomena, more or less distinct at each pole, there is always an orange tint, of greater or less intensity, at some point of the equator. What purpose do they serve, these electric manifestations, continually exhibited throughout the atmosphere of the earth? We are not yet in a condition to say, but De La Rive has thrown much light upon the question.

When, a hundred years ago, Priestley discovered oxygen, the agent of combustion and respiration, medicine found a valuable auxiliary, and enthusiasts saw in it a means of prolonging life. The experiments of M. Bert, however, proved that this vital air, if inhaled into the lungs in a pure state, was a mortal poison. This same oxygen, as soon as it is electrized, shows that it is accompanied by a very odorous substance, blackening colored bodies, irritating violently the respiratory organs, and converting animal products into saltpeter. This is the ozone M Schönbein, the celebrated professor of Basle, found at times in the atmosphere, particularly when the latter was electrized by thunder-clouds. Auguste De La Rive and his learned friend M. de Marignac maintained that ozone is a modification of oxygen, a conclusion rendered incontestable by our two eminent associates, MM. Frémy and Becquerel, jr.

If pure oxygen is deadly in its effects, mingled with the air that surrounds us, it supports life; and if oxygen, ozenized, is a poison, in moderate doses, it purifies the air and fertilizes the soil broken by the plow, giving to its products their agricultural significance.

If it is chance that provides the atmosphere with only just enough of this useful yet dangerous oxygen to support respiration; that brings into being ozone to destroy the deleterious influences which threaten our lives, and to prepare the nourishment necessary for the plants which supply us with food; if it is this same chance which fixes the limits to the concentration of oxygen, rendering almost immutable the quantity of inert gas mingled in the air that we breathe; which renders possible and durable for centuries the existence of man upon the earth, then we must conclude, with Auguste De La Rive, that chance is very intelligent; indeed, so intelligent as to deserve another name.

A flourishing industry, which was commenced about thirty-five years ago, under the auspices of the Academy of Sciences—that is, electroplating—originated in the experiments and practical applications of our respected associate. Up to that time the only mode known of gilding bronze was by the use of mercury. This process produced a good and solid surface, but was fatal to the workmen, as their hands were brought in contact with the dangerous metal, and their lungs exposed to the action of the mercurial vapors during the heating of the articles to be gilded. The old academy offered a prize to any one who would obviate the danger attached to this industry, but it was unclaimed. The present academy was more fortunate. But, if the industry is indebted for its stimulation to the galvanic process, we should not forget that the first pieces gilded by electricity came from the hands of the sagacious and disinterested physicist whose labors we are contemplating. Thanks especially to him, we are spared the distressing spectacle formerly presented by hundreds of unfortunate workmen, involuntary witnesses of the deleterious effects of mercury, who, trembling in every limb, were diseased alike in mind and body.

Auguste De La Rive was a lover and patron of the fine arts, and it was in some sort under his direction that the celebrated painter of Alpine scenery, Calame, executed his chef-d'œuvre, Mount Rose, the most beautiful ornament of the parlor of the scientist. It represents a rugged, lonely scene, a high plateau in the mountains, without verdure or any trace of the presence of man. In the background is the Alps, in the foreground a small, dark lake and some rocks; that is all. But it is nature in her majesty, flooded with the light and enveloped in the pure transparent atmosphere of the mountains—an unadorned exhibition of her grandeur, affecting powerfully the imagination.

Our philosopher was never tired of the beautiful spectacle presented by the effect of the setting sun upon Mont Blanc, and was led to some interesting scientific observations of the phenomenon through his admiration of its picturesque aspect. At the moment when the sun disappears from the horizon, the valley is covered with shade, and the mountain is gradually obscured from the base to near the summit. This alone, for some time, remains illuminated, and, suddenly, while the rest of earth sinks into deeper shadow, takes a bright orange tint, sometimes a bloody or fiery red, and appears like an immense meteor, fixed, incandescent, not belonging to earth, but suspended in the sky. Soon the ever-increasing shade invades even this icy pinnacle. Its outlines grow indistinct, and its color fades to a cadaverous hue. Like the change from life to death in the human face is this rapid transformation from the brilliant tints of departing day to the livid tone which follows upon the forehead of this giant of rock and snow. No one can witness the solemn spectacle for the first time without profound emotion; and the instinctive silence that falls upon the spectator is like the prelude to a prayer. As he turns sorrowfully away, and asks if all is over, suddenly, as if in answer, the mountain is colored anew with a pale rose tint, the reflection of its former splendor. Is the colossus about to revive? No; this fugitive tint is soon effaced, and darkness covers the scene.

The rosy glow, the day's farewell to the snow-clad peaks of these high mountains, is only the reproduction in a particular form of the general effects of the setting sun upon clouds. But what is the cause of the second coloration? Our associate, after many observations of the summit of Mont Blanc, most frequently subjected to the phenomenon, attributed it to the reflection of the last red rays from vaporous strata accumulated in the upper regions of the atmosphere. He studied the nature of these vapors, and invented an apparatus for measuring the variations in the transparency of the atmosphere, which are closely observed by the mountaineers, as they judge from them what weather to expect. If the air is perfectly clear, and distant objects plainly visible, the mountains seeming close to the observer, and the sky of a deep-blue color, they will tell you that rain is near, though there may be no other sign of its approach. If the weather is decidedly fine, the air is not perfectly clear, but is pervaded by a bluish vapor, the sky is moderately blue, and mountains seem far away.

Auguste De La Rive supposed that these vapors, characteristic of fine weather, were composed of mineral and organic particles, which float in the air as long as they are dry, but fall to the ground when surcharged with moisture. They are so abundant, that they take from the air its transparency, which is restored when they disappear. The insects which buzz about us are governed by the same law. If the swallows fly close to the ground at the approach of rain, and high up in the air in fine weather, it is because in the first case the insects upon which they feed are weighed down by moisture, while, in the second, relieved of this burden, they mount higher into space.

The ardor of Auguste De La Rive for the study of electricity could not be satisfied with only the labors of the laboratory. He conceived the plan of a work which would make known all the results obtained in every branch of this department of physics. Familiar with every science, and speaking all languages, he hoped, by uniting and tracing to their source the materials scattered through the periodicals of different countries, to furnish geometers the means for the basis for a new and better theory of electricity. The three volumes of his *Treatise upon Theoretical and Practical Electricity* contain a statement of all the facts observed, with the comment of savans and his own opinion in regard to each one of them. There never was a more impartial compiler nor disinterested narrator. The work shows throughout with what perseverance each individual question was examined, and the care with which they were all subordinated to a general and high order of ideas. "I construct," said he, "a ladder to the top of which I shall never climb, but, as a conscientious workman, I wish those who shall mount it to find every round of good material, solid, and without defect."

The Bibliothèque Universelle de Genève numbered Auguste De La Rive among its most faithful contributors for nearly half a century. He for a long time directed with indefatigable zeal not only the scientific division considered as his natural domain, but also the literary department, in which he was at first regarded as a usurper. The public acknowledged that, in assuming the control of the periodical, he insured for it an important scientific value, but questioned the wisdom of intrusting the literary part to the direction of a savant, considering that the study of science tends to lessened sensibility to the delicate charm of letters. But never had this portion of the review been as replete with matter of an interesting and entertaining character. Many of the charming productions of Töppfer first saw in it the light of day, and if this amiable artist manifested great vigor in his humorous sketches, Auguste De La Rive also showed his good taste in selecting and appreciating the merit of these effusions.

It was not without reflection that Auguste De La Rive partially abandoned his laboratory and favorite studies, to devote a portion of his time, talents, and fortune to the support of a scientific and literary publication which, from the beginning of the century, sustained the moral and intellectual authority of Geneva. He was convinced that the *Bibliothèque Universelle* exercised, like the Edinburgh Review, a salutary influence. The articles selected gave full information on all the important questions of the day, although regarding them from a national point of view, and thus, while imparting knowledge, kept patriotism alive. His comments upon literature and art, full of elevated sentiment and respect for human understanding, left a very pleasing impression upon the mind of the reader. Nothing was admitted into the journal which could not be read aloud in the parlor, or could cause uneasiness to the mother of a family. Somewhat of puritanism in ideas, and a certain austerity in conduct, was not displeasing to De La Rive. He admitted that, if carried to excess, these qualities became ridiculous; but their absence he thought led to disorder. A small country, he said, can exist only under the double condition of having a fixed faith in certain principles, and in conforming the life to them; it must have a physiognomy of its own, and keep it intact; must be itself, and not everybody else; must preserve its own identity, a very difficult matter when railroads tend to mingle all the world into one community—impossible, unless from time to time some voice of authority brings into harmony the discordant elements of society.

In 1815, when Switzerland regained her ancient liberty, Geneva became the temporary abode of many illustrious persons politically distinguished. Some came to enjoy the natural beauty of the shores of Lake Léman, or to rest for a few days in this celebrated city, placed at the confluence of the routes from the north of Europe, from France, and from Italy; others, banished from their native land, sought an asylum among its hospitable inhabitants. Never was there a more singular mingling of the people of every nation, of the representatives of all the continental countries, many of whom had met before on the field of battle, and of England, which had been separated from the rest of Europe for more than thirty years, with the sons of the East, unmistakable in their peculiar type of humanity. In the streets every kind of costume appeared, every language was spoken; in the social assemblies every nationality fraternized.

Meanwhile the Genevese legislators, intrusted with the formation of a constitution for the canton, and anxious to obliterate all traces of the long alliance with the forms of the French administration, found, in the Parliament of England and its controlling aristocracy, the beau-ideal of government. Political party-spirit soon attained as great a degree of intensity in this as in countries of much larger extent. Everybody was in favor of a constitutional government; but while with some, veritable tories, the principle of authority was supreme, with others, true whigs, the idea of liberty was uppermost, and, as usual in such cases, neither side was willing to make concessions. Gaspard De La Rive, first syndic of the republic, was at the head of the conservative division, while his son, in common with most of the young men, belonged to the liberal party, prominent among whom was a former member of the French Academy, Simond de Sismondi.

Auguste De La Rive was too ardent in temperament and too truly patriotic in feeling to be indifferent to the political events which later threatened the tranquillity of his country. Still professing liberal principles, as in the days of his youth, he determined to resist the encroachments of a turbulent and oppressive democracy, and became in his turn the leader of a new conservative party.

After the revolution in Geneva, and at the time of the Sonderbund war, he resigned his professorship and retired from public life. Still, when, on the annexation of Savoy to France, some uneasiness was felt by the Helvetic government, he was sent to London, as minister plenipotentiary and envoy extraordinary, to guard the interests of the Confederation. He was treated by the Queen with the highest distinction, and on his return to his native land received a new mark of confidence; he was made a member of the select assembly for the revision of the constitution of Geneva. And when his term of office was completed, he resigned entirely all share in the government of his country.

He could not forgive a revolution which could tempt from the culture of intelligence the vigorous offspring of noble and opulent families, to immerse them in business affairs. The recognized superiority of his native city over many others greater in extent and population, he explained, not by its position upon the shores of Lake Léman, nor by the beauty of its surroundings, nor yet by its great trade in watches. He attributed all its importance to the brilliant assembly of thinkers, philosophers, writers, and savants who had rendered it illustrious. Voltaire, Rousseau, Madame de Staël, for instance, would never be forgotten; and the beautiful investigations of Charles Bonnet in natural philosophy; the discoveries of Tremblay in regard to polyps; of the blind Huber concerning bees, and his son in respect to the habits of the ant; the Alpine journeys of Horace Benedict de Saussure, one of the founders of geological science; the works of Senebier and of Theodore de Saussure upon the physiology of plants, could not be effaced from the great book of human knowledge without injuring the intellectual prospects of future ages. The academy and the venerable ecclesiastic company had been the soul of Geneva, and he could not see without uneasiness their influence diminish. He was right. Alexander victorious did not save Macedonia from forgetfulness; Athens, so often invaded, has survived her misfortunes, and will always live in the memory of man. War may make slaves and reduce to impotency the limbs of the vanquished, but she cannot touch the human mind nor the imprint it leaves upon the religion, philosophy, letters, science, and art of its masters.

Geneva, like Florence, considered that her real existence lay in the noble minds that made her famous, but the fears of De La Rive for her future were without foundation. To the wise generation of the last century and the commencement of the present, to which he belonged, has succeeded a people full of vigor and worthy to occupy the palace raised by the provident city in honor of science. In this privileged country, thanks to the example of our associate and of his assistant laborers, as well as to the liberal institutions inspired by him, the youthful representatives of noble and ancient families are more ready to look upon fortune as a means of advancing knowledge than to value learning as an assistance in the acquirement of material prosperity.

The interests of Auguste De La Rive were not all centered in Geneva. A large share of his thoughts and affections were reserved for Présinge, an estate of considerable extent, ancient tenure of the dukes of Savoy. The family of La Rive had been in possession of this patriarchal domain for several centuries, and for generations the surrounding agricultural population were benefited by the influence of its amiable representatives. Gaspard De La Rive and his son no doubt did much to foster the hatred of display, the active benevolence, absence of pride, and aversion to pedantry, which are characteristic in Savoy of the habits and manners of the gentleman.

His quiet life in this peaceful retreat was troubled by the material speculations of the age, which he regarded with more solicitude than most of his countrymen. Attached to the truths of the Christian religion, he was a member of the Protestant Church of Geneva, but his respect was great for the Roman Catholic faith, which was professed by many of his relations and friends, and by the larger part of the resident population in the neighborhood of Présinge, among whom he lived, loving and beloved, sharing all their interests, moral and religious, even to the building of their church. In what times of religious disorder we live, he said, and how science is implicated. In our youth, full of enthusiasm for her, we little thought a day would come when she would deny the assertion of Bossuet, "Were man openly to declare himself God, his pride would revolt at such presumption; but to call himself God, and yet feel himself to be mortal, is to shame even the blindest arrogance."

The spirit of tolerance, so natural to our associate, led him to avoid everything that would wound the convictions of others; but there came a time when to keep silent was to deny his faith, and he did not wish the world to think that those who advocated materialism in the name of science were sure of the approbation and complicity of all savants. It is by no means the case, he said, with decision, and it is our duty to say so. Science is great; her *role* is glorious; but her domain is circumscribed. She commands matter, but has no control over mind. We can better explain the course of the stars than the astronomers of the time of Homer, but have added nothing to our knowledge of the human passions he so vividly portrayed. Our ideas in regard to heat are more certain than those of Eschylus, but concerning oppression and wrong they have not changed since the protestations against tyranny and brutal force of the author of Prometheus Bound. We are better acquainted than Virgil with the action of the heart in the circulation of the blood, but have discovered no new sentiment of pity or tenderness. Man does not need science to sound the depths of the human soul, and the study of the physical forces shows that between them and the moral attributes there is nothing in common.

Many associations connected De La Rive with England, formed during his residence as minister in that country, and with France he was united by friendship with many of its distinguished men, among whom were M. de Tocqueville and M. de Montalembert. With Savoy and Italy ancient family relations had been revived and strengthened by an affectionate and close intimacy with his relative, the count of Cavour, who was, from his earliest infancy, accustomed to spend every year several weeks at Présinge. In early life the young savant and the future statesman who was to exercise so great an influence upon the destinies of Italy, were for a long time in perfect accord upon the ground of liberal ideas. Surrounded by influences unfavorable to their convictions, they enjoyed together the forbidden fruit; and sometimes in the evening, in the parlor of Présinge, while their elders slept by the fireside, would scandalize the feminine portion of the family circle by exaggerated expression of their opinions, which their troubled audience dared not oppose for fear of awakening those in whom these views would have excited the utmost consternation. In later years this union of sentiment was gradually dissolved, Cavour, through struggling with absolute governments, became more and more a partisan of liberty, while De La Rive, disgusted with the unreasonable demands of democracy, united himself more and more closely with the conservative party. Their friendship, however, was never disturbed, and if the bust of the statesman occupied in the parlor of our associate a place of distinction opposite that of the celebrated Rossi, on the other hand Cavour never could speak of the savant except in terms of tender affection and profound respect.

M. Auguste De La Rive was, to an unusual degree, favored in the circumstances of his life. The scion of an illustrious family, of a spotless name, educated by a father of large heart and noble understanding, master of a fortune which allowed free pursuit of his studies, and residing in a country where he was appreciated at his proper value, he passed his days in unbroken prosperity and in the quiet enjoyment of the pleasures derived from a love for letters and the fine arts, the culture of science, the practice of benevolence, devotion to his country, and the joys of domestic life. When, after having long been a correspondent of the French Academy, he was made a member, he wrote to me, "I have nothing now to wish for; my desires are more than satisfied." A portion of the year he passed in his city residence, the remainder of the time in the country at Présinge, and in both places he exercised a generous hospitality. Favorable as destiny had been to him in life, his death was followed by a series of distressing events. In one short month, his brother, who was united to him by ties of the tenderest affection, his relative and friend M. Jules Francois Pictet, one of the most eminent naturalists of the day, two of his sons-in-law, and Madame Quetelet, who in her sorrow survived him only a few days, had also passed away. As we visit his deserted laboratories, the scene of so many interesting discoveries, and wander, in imagination, through his two abodes, so full of happy memories; through the silent halls whose echoes might repeat the noble words of one of the greatest philosophers of the century, the heart is oppressed with grief. But we remember that the eminently good man, the illustrious and venerated savant, whose presence we seek in vain in these now melancholy abodes of sorrow, will live forever in the ineffaceable record of the past. Auguste De La Rive, far from the belief that, on leaving this world, he would sink into nothing, as the ephemeral vapor is dissipated in the rays of the sun, placed full confidence in a future reserved for man, in the hope of another and higher state of existence. There is consolation in the thought that he leaves behind him two sons worthy to be his successors, as well as a son-in-law, and three daughters, whom he regarded with great tenderness, and who will cherish with veneration and transmit to his descendants his noble example of patriotism, benevolence, and respect for labor. But the homage we render him is not confined to this world; it mounts to the happy regions where he dwells an immortal soul, and worthy of his immortality.

ON TIDES AND TIDAL ACTION IN HARBORS.*

By PROFESSOR J. E. HILGARD, OF THE U. S. COAST SURVEY, WASHINGTON, D. C.

LADIES AND GENTLEMEN: I propose to engage your attention this evening with the subject of the tides of the ocean and the influence exerted by tidal currents on our harbors. I shall first briefly describe the phenomena of the tides as they present themselves to an observer, then consider the physical causes to which these phenomena are due, next examine more in detail the phases of the tide on our own coasts, and finally describe the tidal hydraulics of the magnificent harbor of New York.

The most obvious change in the surface of the ocean to be noticed upon our shores is the alternate rising and falling regularly twice in every day. Closer attention will show that the tides of each day occur somewhat later than those of the preceding day, the average time of retardation being fifty-two minutes, and that this retardation corresponds to that of the moon. It will pass as a fair approximation to say, that it is high water at New York with a southeast moon, or similarly for New Castle, on the Delaware, that high water occurs when the moon is south In fact, so closely is the time of tide connected with the position of the moon, that in order to give the time of high water upon any day approximately it is customary to state the time of high water on the days of the new and full moon, when the moon passes the meridian at twelve o'clock, nearly. This time is called the "establishment of the port." Then, to find the time of high water on any other day, it is only necessary to add the "establishment" to the time of the moon's meridian passage on that day. On closer examination, it will be found that the interval between the time of the moon's passage over the meridian and the time of high water, called the *luni-tidal interval*, varies with the moon's age very sensibly. Moreover, the elevation at high water and depression at low water will not always be the same, but will be greatest about the times of new moon and full moon, and least about the first and third quarters. The details of these variations will be best traced out in connection with the explanation of their causes, to which we will now proceed.

The popular explanation of the tides, as depending on the law of gravitation, is sufficiently simple, although the complete mathematical investigation of the subject, by which we should be enabled to predict their occurrence and magnitude for any place, is encompassed with difficulties, from causes to which we shall hereafter revert.

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* Delivered before the American Institute, January 27, 1871, with revision.

If we conceive the earth to be wholly, or for the greater part, covered with water and subject to the attraction of the sun, the force of which varies inversely as the square of the distance, it will be obvious, that while the whole earth will fall toward the sun with a velocity proportioned to the aggregate attraction upon its solid portions, (which is the same as if all the matter were collected at its center,) the water nearest to the sun being accelerated by a greater force, and being fluid, will approach the sun more rapidly than the solid core. It will thus run from all sides into a protuberance beyond the form of equilibrium of the earth's attraction and rotation, until the pressure of the elevated mass equals the difference in the attraction of the sun. Moreover, a similar protuberance will be formed on the side opposite to the sun, since the particles of water, being solicited by a less force than the solid core, will fall more slowly toward the sun, and as it were remain behind. Nor does the fact that on the average the earth does not lessen its distance from the sun, in the least invalidate the force of this reasoning; for the deviations from the tangential motion of the earth in its orbit are precisely those which the earth would move through if falling toward the sun unaffected by any other impulse.

The same considerations hold good in regard to the attraction of the moon upon the earth and the waters surrounding it; for although we are in the habit of considering the moon as simply revolving about the earth, it must be remembered that the attraction is mutual, that both bodies describe orbits about their common center of gravity, and that while the moon obeys the attractive force of the earth, the latter equally follows that of the former, by which it is at every instant of time drawn from the path which it would pursue if that influence did not exist by an amount precisely equal to the fall corresponding to the moon's attractive force.

As a necessary consequence of the elevation of the water in the regions nearest to and most remote from the attracting body, there must be a corresponding depression below the mean level of the sea at points distant ninety degrees from the vertices of the protuberances, or at the sides of the earth, as seen from the sun or moon. If the latter bodies maintained a constant position with respect to the earth, the effect would therefore be to produce a distortion of figure in the ocean-surface, (assumed to cover the whole earth,) having the form of a slightly elongated ellipsoid, the two vertices of which would be the one precisely under, the other precisely opposite to, the points at which the disturbing body is vertical. This, however, is not the case; for by the rotation of the earth, and the motion of earth and moon in their orbits, the direction of the disturbing forces is constantly changing with respect to any point on the earth's surface. New points arrive at every instant under the zenith and nadir of either luminary, and thus it is that waves are produced which follow them round the globe. The highest points of these waves will remain far behind the verticals of the disturbing bodies, because the inertia and friction of the water prevent the rapid change of form required, and because, although the elevating force is greatest under the vertical, it still continues to act in the same direction for some hours after the passage of the luminary, with but little diminished force.

This retardation, which would be sensible under the simple supposition of an uninterrupted ocean covering the earth's surface, becomes very considerable under the actual circumstances of the case. The depth of the sea varies so much, and the form of its basin, taken as a whole, is so interrupted by the land, that no regular progressive movement of the tide-wave can take place, except in the great Southern Ocean. At all points on the coast the phases of the tide will follow the periodicity of the forces causing them, but at each point, at a greater or less interval from the culmination of the sun or moon, according to its local position, and the more or less circuitous course taken by the tide-wave to reach it. This interval and the actual rise and fall of the tide must be determined for each place by special observation.

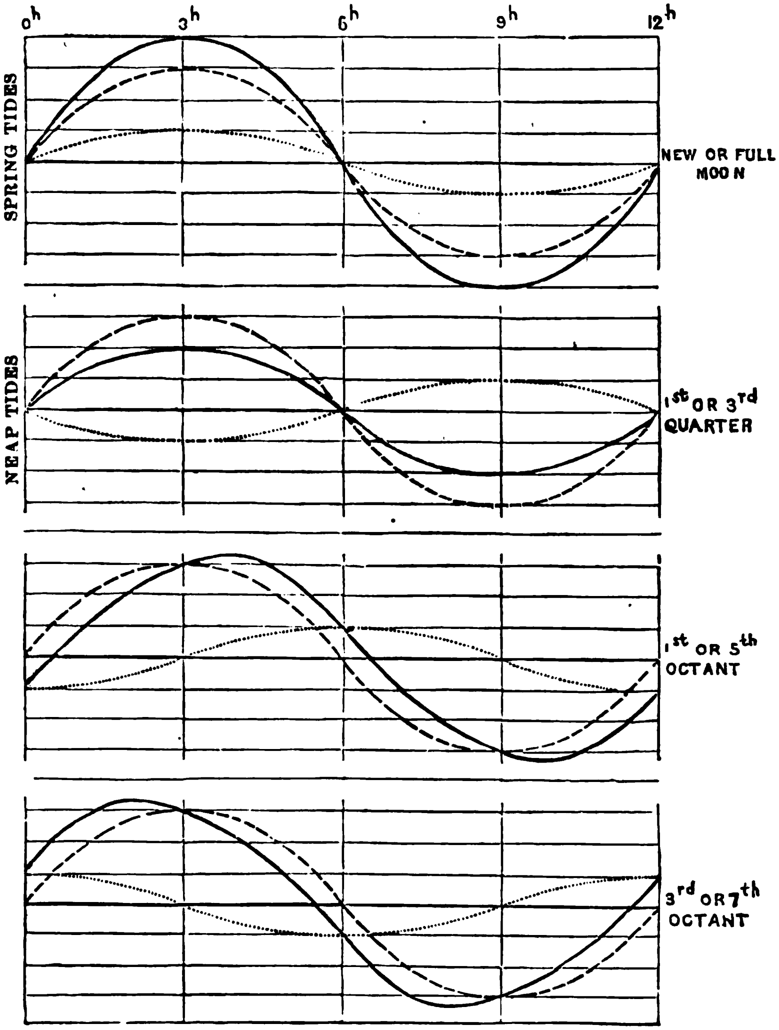
LUNI-SOLAR PHASES OF THE TIDES.

The close relations which the times of high water bear to the times of the moon's passage show that the moon's influence in raising the tides must be much greater than the sun's. In fact, while the *whole* attraction of the sun upon the earth far exceeds that of the moon, yet owing to the greater proximity of the latter, the *difference* between its attraction at the center of the earth and at the nearest or most remote point of its surface, which difference alone produces the tides, is about two and a half times as great as the difference of the sun's attraction at the same points.

SEMI-MONTHLY INEQUALITY.

We will now consider the particular phases resulting from the combination of the lunar and solar tides, and from the varying positions of those bodies. There will be two complete lunar tides in every lunar day of twenty-four hours fifty-two minutes, and also two complete solar tides in every mean solar day of twenty-four hours. These are known as the semi-diurnal tides, and constitute the principal variations of the sea-level. The combined effect of these two fluctuations will be most readily understood by reference to the annexed diagram, in which the lunar tide is represented by dashes, the solar by dots, and the combined or actual tide by a full line. At the time of syzygies, or full and change of the moon, the effects of both sun and moon combine together to produce the *spring-tides*, when high water is higher and low water is lower than at mean tides by the amount of the solar tide. At quadratures the high water of the sun will combine with the low water of

SEMI-MONTHLY INEQUALITY



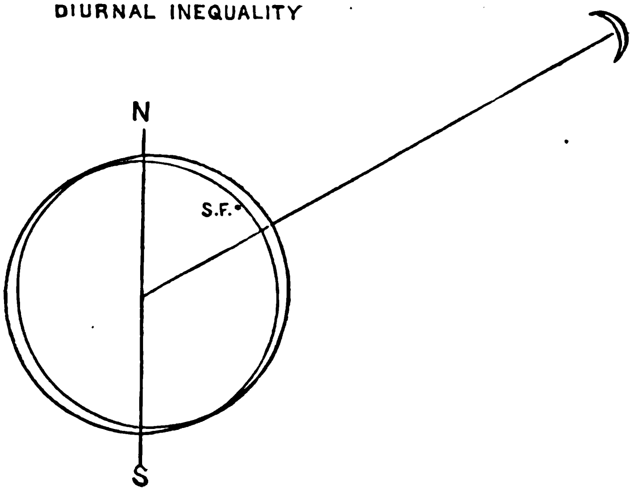
the moon to produce a less fall, and the low water of the sun with the high water of the moon to produce a less rise than at mean tides; and we have the *neap-tides*, the range of which is less than the mean range by the amount of the solar tide. Thus, at New York, the rise and fall at syzygies is 5.4 feet, at quadrature 3.4 feet, the former being the sum, the latter the difference of the lunar and solar tides, whence we obtain for the effect of the moon 4.4 feet and for that of the sun one foot, or a ratio of forty-four to ten. This proportion does not prove to be the same in all parts of the world, and even varies considerably in places not far distant from each other. At Boston the heights are 11.3 and 8.5 feet, respectively, giving a proportion of seven to one. On the Atlantic coast of the United States it averages about five to one, while on the east side of the Atlantic Ocean, on the coasts of France and England, it is in many parts as three to one. These differences are to be ascribed to the fact that the shore and harbor tides which we observe have in every instance acquired a greater magnitude than the ocean tides, in consequence of the wave having passed over a sloping bottom and having been greatly retarded by the effect of friction. A comparison of the range of spring and neap-tides, therefore, will not serve as a correct measure of the relative effect of the sun and moon, unless the effect of friction were taken into consideration, which we are at present unable to do for want of a complete knowledge of the configuration of the bottom.

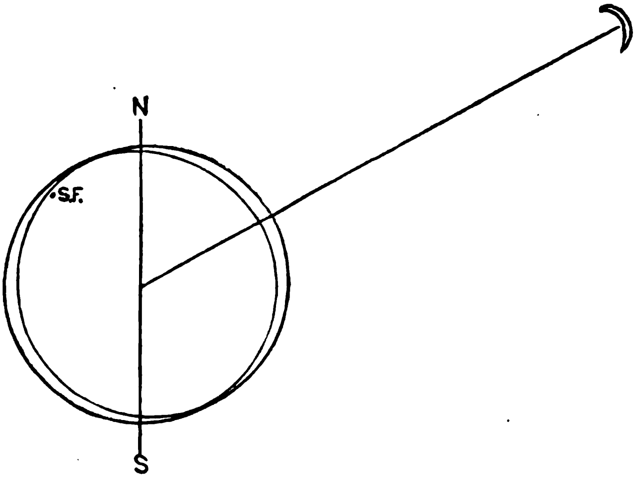
The interval between the moon's meridian passage and the time of high water is subject to a variation similar to that of the height. On the day after the spring-tides, the top of the solar tide-wave will be nearly an hour in advance of the lunar tide-wave, and the two waves will combine to make high water earlier than the moon's alone would bring it. It will continue to be earlier until the moon's transit is later by three hours, or in the first octant. It then falls back until it is latest in the third octant, and again advances, until, at the next spring-tides, it reaches its mean period. The mean of all the luni-tidal intervals for half a month at a port its called its *mean establishment*, which is used for finding the time of high water on any given day; and tables are constructed from observations at the principal ports for finding the correction for semi-monthly inequality due to the moon's age. Thus, for New York, the mean luni-tidal interval is 8h. 13m., and its least and greatest values are 7h. 52m. and 8h. 35m. On the Atlantic coast of the United States the range of this inequality is about three-quarters of an hour; on the coasts of France and Great Britain it often exceeds one and a half hours.

DIURNAL INEQUALITY.

The next variation of the tides to be considered is that dependent on the moon's declination. Were that body constantly in the plane of the equator, the highest points of the tide-waves would also be in that plane, and would consequently produce a series of equal tides at any place either north or south of the equator. But it is evident that, when the moon ascends to the north, the vertex of the tide-wave will tend to follow it, giving the highest point of one tide in the northern, and the highest point of the opposite tide in the southern, hemisphere. Consequently, when the moon has a northern declination, the tide at any place in the northern hemisphere caused by its upper transit will be higher than that caused by its lower transit. (See diagram of diurnal inequality.) This variation in the heights has a period of one lunar day, and is called the *diurnal inequality;* it reaches its maximum when the moon is at its greatest northern or southern declination, and disappears when it is on the equator, and consequently has a half-monthly period. The variations of height from this cause produce a corresponding inequality in the times of high water. The sun's declination affects the tides in a similar manner, but the amount of the disturbance is very small, and its period extends over half a year. In long series of observations its effect is nevertheless well marked, both in height and time. The diurnal inequality, depending upon the moon's declination, is, on the other hand, quite sensible, and in many places constitutes a prominent feature of the tides, as on the Pacific coast of North America.

DIURNAL INEQUALITY





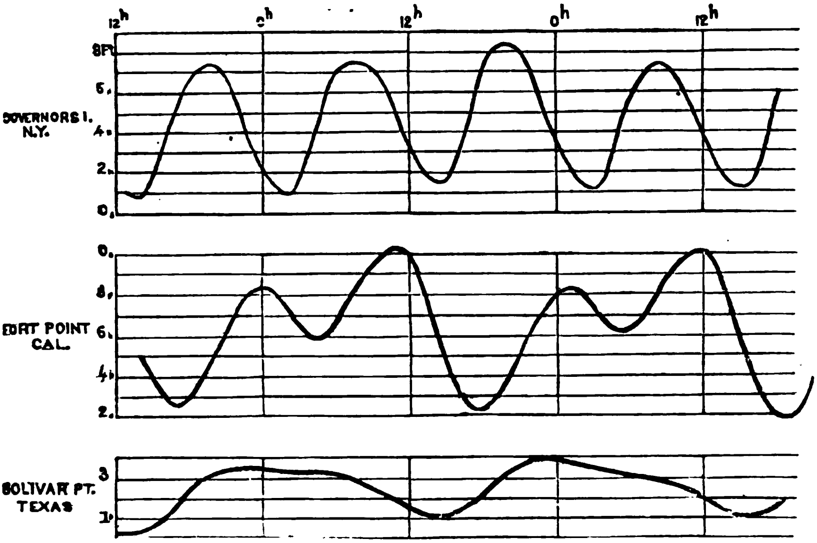
PARALLACTIC INEQUALITY.

A further cause in the variation of the height of the tides is the variation of the distances of the sun and the moon by reason of the ellipticity of their orbits. The efficacy of a heavenly body in raising tides is shown by theory to be inversely proportional to the cube of the distance. Hence the efficacy of the sun will fluctuate between the extremes nineteen and twenty-one, taking twenty for its mean value, and that of the moon between forty-three and fifty-nine. Taking into account this cause of difference, the highest spring-tide will be to the lowest neap as 59+21 to 43—19, or as eighty to twenty-four, or ten to three; leaving out of consideration the local circumstances of access and depth, which, as we have stated, modify those proportions in a marked degree.

TYPE CURVES.

The three principal forms of tides are illustrated in the annexed diagram, which exhibits the tides at New York, San Francisco, and Galveston for two days from actual observation. Of these, that for San Francisco may be taken as the normal type, showing the diurnal inequality, while that at New York, as at other ports on the Atlantic coast, is not sensibly affected by it. The explanation of this feature is probably to be found in the supposition that the tide-wave which advances up into the Atlantic Ocean from the continuous tide in the Southern Ocean arrives on our shores twelve hours later than the direct tide-wave which crosses the Atlantic from east to west. In this way the diurnal inequality will be eliminated by the superposition of the two tides, the greater high water of the former coinciding with the lesser of the latter, and *vice versa*, leaving the semi-diurnal tides of equal height.

TIDE REGISTERS



The tide at Galveston, on the other hand, furnishes a case of the elimination of the semi-diurnal tide, leaving as a residual only the diurnal inequality. It is to be presumed in this instance that the tides reaching Galveston through the straits of Florida and through the passage between Cuba and Yucatan differ by six hours in their periods, causing the low water of one to coincide with the high water of the other, thus sensibly destroying the semi-diurnal tides, except in so far as they are unequal. This leaves a small tide outstanding, having substantially the form of the diurnal inequality, and producing the appearance of the "single-day tide," or one high and one low water in every twenty-four hours. This residual fluctuation is well marked at times when the moon's declination is considerable on either side of the equator, but disappears almost entirely when the moon is near the equator, since, at such times, the diurnal inequality disappears. Tides of this class have always a small range; in the Gulf of Mexico they rarely exceed two and a half feet, and the average rise and fall is but one and a half foot.

The tides on the coasts of the United States have been specially investigated by Professor Bache, the late Superintendent of the American Coast Survey. In connection with that work he organized an extensive system of exact tidal observations, for the purpose of ascertaining the complicated laws which govern the tides of the seas that wash our shores. It will be readily understood that in order to separate the effects of the different causes which modify the phenomena, it is not sufficient to observe merely the heights and times of high and low water, but that a continuous record of the tides is necessary, as the inequalities are constantly shifting their place and magnitude.

TIDE-GAUGES.

For this purpose a self-registering tide-gauge is used, by which a continuous curve, representing the successive changes in the height of water, is traced on paper, moved by clock-work, by a pencil actuated by the rising and falling of a float in a vertical box, to which the tide has free access. The time-scale is such that every hour is represented by one inch, and is pricked into the paper by points on the cylinder which moves the paper forward. The scale of heights is so adapted to the range of the tide at the place of observation that the extreme range of the curve will not exceed the width of the sheet—twelve inches. A continuous sheet, sufficient for the record of a whole month, is put on the tide-gauge at one time. A complete description of this instrument will be found in the United States Coast Survey Report for 1853. [The lecturer illustrated the construction of several tide-gauges by means of diagrams.]

In northern ports interruptions are experienced in winter from the float-box becoming clogged with ice, and various devices have been resorted to for overcoming this difficulty. One of the most effective has been that of maintaining a temperature above freezing within the float-box by means of a simple heating-apparatus. An arrangement of this kind has actually been used on the Fox Islands, in Penobscot Bay. A stream of water flows slowly from an elevated hogshead through a coil in a large stove, passes down to the bottom of the float-box and up again into another hogshead, from which it is pumped up every day by the observer into the first one. As but a small elevation of temperature is necessary, this arrangement has proved quite sufficient.

Another arrangement, devised by Mr. Batchelder, of Boston, and called by him an "Arctic tide-gauge," is in use at Boston, and has compared well with the ordinary float-gauge. It consists of a strong iron tube, about four inches in diameter, firmly bolted to a wharf or pile. It is open at the top, and has at the lower end a nipple, to which an India-rubber bag is fastened; the length of the tube being sufficient to allow the elastic bag to be always submerged at the lowest stage of the tide. The bag is supported by a suitable shelf or cage, and is filled with glycerine, which is poured in at the top of the tube. When in this condition the glycerine rises and falls within the iron tube in proportion to the varying height and pressure of the column of water above the rubber bag, the difference in the height of the two columns being in proportion to the difference of the specific gravity of the water and the glycerine. The parts above described insure protection against floating ice, and prevent congelation within the iron tube.

A copper tube about three inches in diameter, closed at the bottom and open at the top, is placed within the iron tube, and floats in the glycerine; if left free, it would rise and fall with the changing level of this liquid. The length of the central tube is a little greater than the whole range of the tide.

Near the upper end of the outer tube there are three spiral springs, fixed at the top and united at the bottom by a plate or disk, from which the central copper tube is suspended. From a stem fixed to the central tube or float, and moving with it, a string or chain leads over a single pulley, and gives horizontal motion to the pencil-carriage of the recording-apparatus.

The distance that the central tube is to move vertically is adjusted to agree with the required range of the pencil upon the record-paper by placing within it suitable weights.

As the glycerine rises or falls in the annular space between the iron tube and the central float, the spiral spring at the top is more or less extended, the extension being uniform on account of the cylindrical form of the float.

It is not necessary that the India-rubber bag be inclosed in a perforated box, for the purpose of preventing oscillation, as it is always submerged, and the pressure upon it is equal to the weight of the column of water, having its base at the bag, and its summit at the mean level of the surface-waves.

A tide-gauge, for observations on an open coast, has been devised by Mr. Henry Mitchell, of the Coast Survey. The graduated scale on the float is read from the shore by means of a spy-glass, the top of the tube serving as index-mark.

PREDICTION OF TIDES.

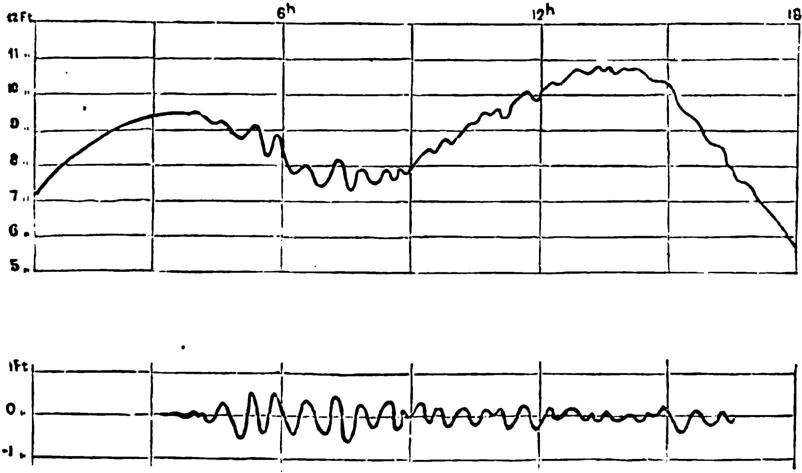
Self-registering tide-gauges have been kept in operation for a number of years at different points on both coasts of the United States, in order to obtain from them the data for predicting the tides; and as a result, tide-tables have been published by the Coast Survey for some years past, giving in advance the times and heights of high and low water for all the principal ports in the United States for every day in the year. In addition to this, the differences are given by which to find the same for intermediate ports.

A very elaborate discussion of the tides observed at Boston during nineteen years, a full lunar cycle, has been made by Mr. William Ferrel, of the Coast Survey, and has resulted in representing the actual tides with unlooked-for precision. By the introduction of the consideration of friction Mr. Ferrel has also succeeded in deriving a value for the mass of the moon, which appears to compete in exactness with the values obtained by astronomical methods. It is one seventy-seventh part of that of the earth.

EARTHQUAKE-WAVES.

The tide-gauges being in continuous operation, all other fluctuations of the ocean-level besides those produced by the tides are likewise registered. The tide-curves of the western coast are frequently found indented by fluctuations arising from earthquakes. A remarkable instance of this kind is given in the annexed diagram of earthquake-waves, which recorded the earthquake that destroyed the city of Simoda, in Japan, in December, 1854. The upper curve is a reduction from the tide-gauge register, while the lower shows the earthquake-waves separated from

EARTHQUAKE WAVES AT FORT PT, AS RECORDED ON THE SELF-REGISTERING TIDE GAUGE.



the tidal wave. The time required for the transmission of the sea-waves from Simoda to San Francisco was twelve hours and thirty-six minutes. The distance being 4,500 miles, the transmission of the wave was at an average rate of 360 miles per hour. The theory of wave-motion teaches us that this velocity will be attained by a free-moving wave in a depth of 1,440 fathoms, which may be taken as the average depth of the Pacific Ocean between Japan and California. It will be observed that the crests of the waves occur at intervals of about twenty-three minutes, corresponding to a length, from crest to crest, of 150 miles. The height when the waves arrived at San Francisco was about eighteen inches from hollow to crest, the high waves caused by the original impulse having gradually flattened out to that form in their transmission across the ocean.

The great earthquake which occurred in Peru, in August, 1868, was likewise recorded on the tide-gauges at San Diego, San Francisco, and Astoria. The fluctuation of the ocean was so great in this instance as to be very sensible to casual observation, and was noted in Australia, at the Sandwich Islands, and at Kodiak, in Alaska. The data obtained from these observations, combined with the result before mentioned, indicate that the average depth of the Pacific Ocean is about 1,800 fathoms.

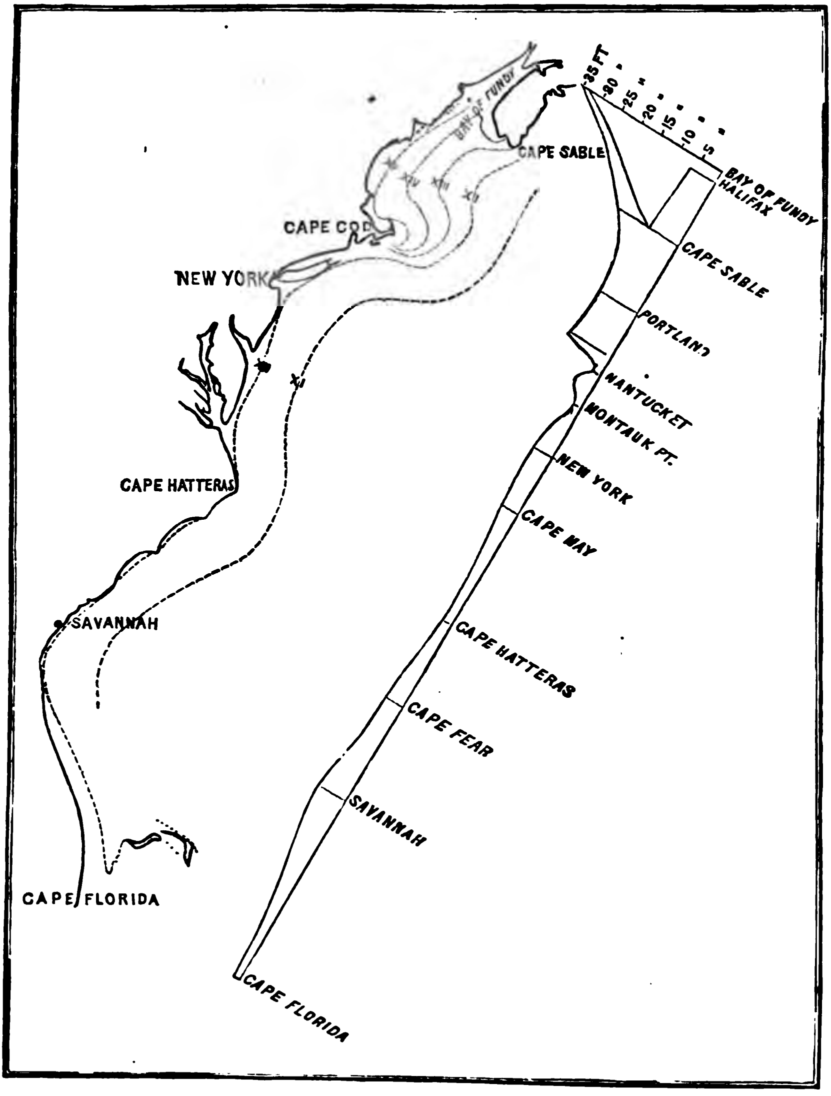
MOVEMENT OF TIDAL WAVES.

The waves above described, originating with an impulse at one definite point, and propagated freely through the ocean in every direction, with a velocity depending upon the square root of the depth of the sea, may serve as good illustrations of the manner in which tides are propagated through sounds, bays, and rivers. The following table gives the rate of motion for different depths:

Depth in feet............	10	Miles per hour...........	12.2
" "	60	" "	30.0
" "	100	" "	38.7
" "	1,000	" "	122.3
" "	6,000	" "	299.5

That movement of the ocean, however, which we have designated by the name of tide-wave, does not partake of the nature of a wave in the common acceptation of the term, but it is rather to be conceived as a general movement of the water toward a point under the attracting body, and again away from it. Its periodicity is strictly dependent upon that of the attracting body. The velocity of the movement is about 1,000 miles per hour on the equator; it extends to the bottom of the ocean, the depth of which is inconsiderable compared with the radius of the earth. It is not attended by a sensible elevation of the water in mid-ocean; and in this respect the characteristic of what we call a wave is absent. The movement may be likened to that of an impulse given to a very long rigid bar, as of iron. In this case, a sensible time will be required for the transmission of the impulse from one end to the other, and during its transmission the particles will successively approach to each other, by which an infinitesimal elevation and subsidence, after the manner of a wave, will be produced. In the same way the transmission of the movement through the incompressible water of the sea is attended with an infinitesimal elevation and recession; but when the movement reaches shallow water, in approaching the shores, the horizontal motion is partly translated into vertical motion upon the sloping bottom; and it is thus that the tides attain sensible vertical height.

TIMES AND HEIGHTS OF TIDES ON ATLANTIC COAST OF UNITED STATES



Now, where a bay or indentation of the coast presents itself, opening favorably to the tide-wave thus developed, and decreases in width from its entrance toward its head, the tide rises higher and higher from the mouth upward. This is due to the concentration of the wave by the approach of the shores and to the gradual shoaling of the bottom.

This effect is strikingly illustrated by a generalization of the heights of the tides on the Atlantic coast of the United States. That coast presents, in its general outline, as represented in the annexed diagram, three large bays: the great southern, from Cape Florida to Cape Hatteras; the great middle, from Cape Hatteras to Nantucket; and the great eastern, from Nantucket to Cape Sable, now known as the Gulf of Maine. It will be seen that the tide-wave arrives at about the same time at the headlands, Cape Florida, Cape Hatteras, Nantucket, and Cape Sable, and that at those points the height is inconsiderable compared with the rise at the head of the several bays. Thus, at Cape Florida the mean rise and fall is only one and one-half of a foot; at Hatteras, but two feet; while at the intermediate entrance to Savannah it reaches seven feet, declining in height toward both capes. Again, at the head of the middle bay, in New York Harbor, it reaches five feet, while on the southeast side of Nantucket Island it is little over one foot. The configuration of the eastern bay is less regular, and the correspondence of heights is not so obvious. The recess of Massachusetts Bay is well marked, the increase in height reaching ten feet at Boston and Plymouth. Rolling on eastward along the coast of Maine, it constantly increases; but the most striking effect of the convergence of shores is exhibited in the Bay of Fundy. At St. John's the mean height of tide is nineteen feet, and at Sackville, in Cumberland Basin, thirty-six feet, attaining to fifty feet and more at spring-tides.

When the wave leaves the open sea, its front slope and rear slope are equal in length and similar in form, but as it advances into a narrow channel, bay, or river, its front slope becomes short and steep, and its rear slope becomes long and less inclined. Hence arises the fact that at a station near the sea, the time occupied by the rise is equal to that occupied by the descent; but at a station more removed from the sea, the rise occupies a shorter time than the descent. Thus, in Delaware Bay and River we have the following relations of the duration and height of rise and fall:

Station.	Mean rise and fall.	Luni-tidal interval.	Mean duration of—	
			Flood-tide.	Ebb-tide.
	Feet.	*h. m.*	*h. m.*	*h. m.*
Delaware breakwater	3.5	8 0	6 18	6 8
Egg Island light	6.0	9 4	5 56	6 30
New Castle	5.5	11 53	5 24	7 2
Philadelphia	6.0	13 44	4 52	7 34

An examination of this table will show, besides the marked increase in the height of the tide due to the contraction of the shores from the capes up to New Castle, a subsequent loss from friction in a narrow channel of nearly uniform character, and correspondingly a rapid propagation of the tide-wave through the deep water of the bay, and a comparatively slow movement along the narrower channel of the river. At the mouth of the bay the duration of rise exceeds that of fall by ten minutes, while at Philadelphia it is less by two hours forty-two minutes. When the tide is very large compared with the depth of water, this inequality becomes very great; thus, in the Severn River, at Newnham, above Bristol, England, the whole rise of eighteen feet takes place in one and a half hours, while the fall occupies ten hours.

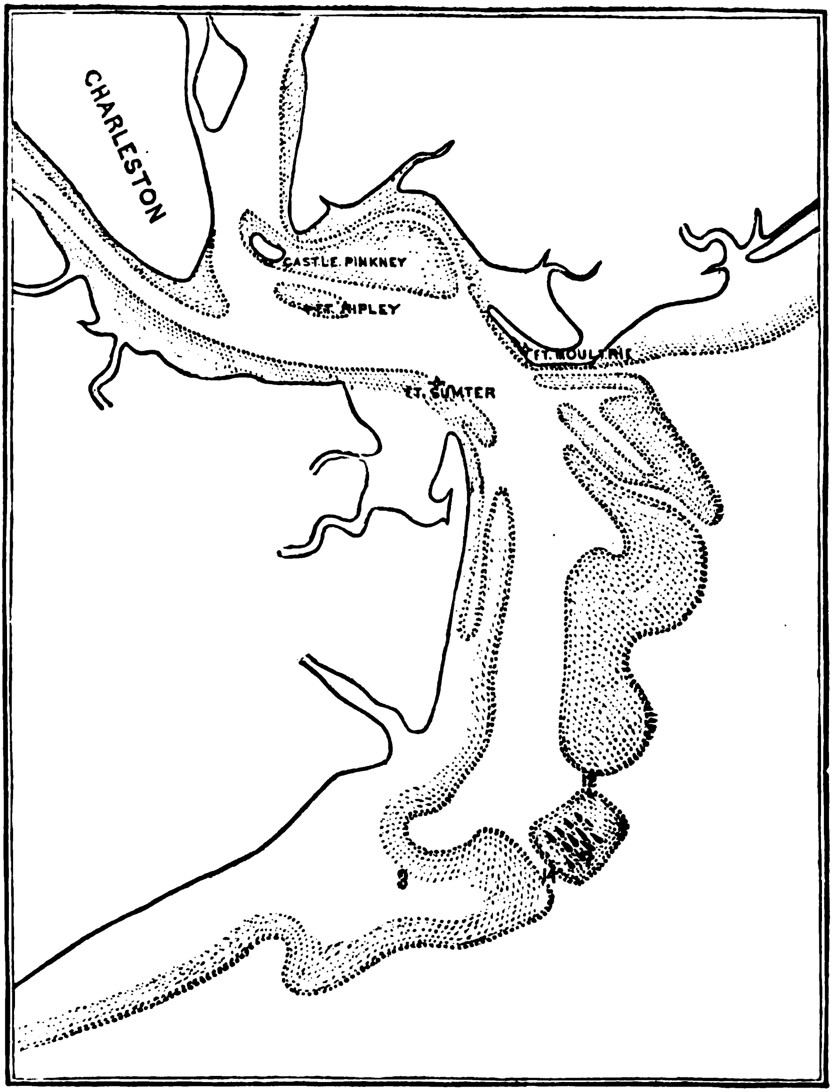
TIDAL CURRENTS.

The agency of tidal currents in producing changes in the entrances of bays and harbors is a subject of the first importance to commerce and navigation, and has received full attention in the prosecution of the American coast survey. The laws according to which the changes take place require to be studied by long-continued observation, and when the change is for the worse, the means of counteracting it must be pointed out.

As on the average the same amount of water moves inward and outward with the flood and ebb tides, we might readily suppose that the same amount of material is transported either way, and that no important change would take place in the configuration of the bottom. But the operation of the flood-stream is very different from that of the ebb-stream. We have, as a general feature, an interior basin of some extent, communicating with the sea by a comparatively narrow passage. The flood-stream, therefore, running with considerable velocity through this channel, will, as it enters the basin, spread out and become slow, depositing the sand and mud it is charged with, and making extensive flats or shoals opposite the entrance. The ebb-stream runs slowly over the flats from all directions toward the opening without removing much of the deposit, and gradually concentrates in definite narrow channels, which it scoops out, and the depth of which will depend in a great degree on the proportion of the area of the basin to the outlet, or, in other terms, on the difference of level which will be reached during the ebb between the basin and the ocean, which determines the greatest velocity and transporting power reached by the ebb-stream.

On the bars of most of the sand-barred harbors on our southern coast, the place and direction of the channel are frequently changed during violent storms; when the direction of the waves happens to be oblique to that of the channel, or when the sea runs directly upon the channel, the depth of water may be considerably diminished for the time being by the sand rolled up by the waves. But in all these cases it is found that the normal depth is speedily restored by the scour of the ebb-tide, which depends upon the unchanged factors of area and form of basin, height of tide, and character of the material forming the bar.

EFFECT OF SINKING STONE-FLEET ON CHARLESTON BAR

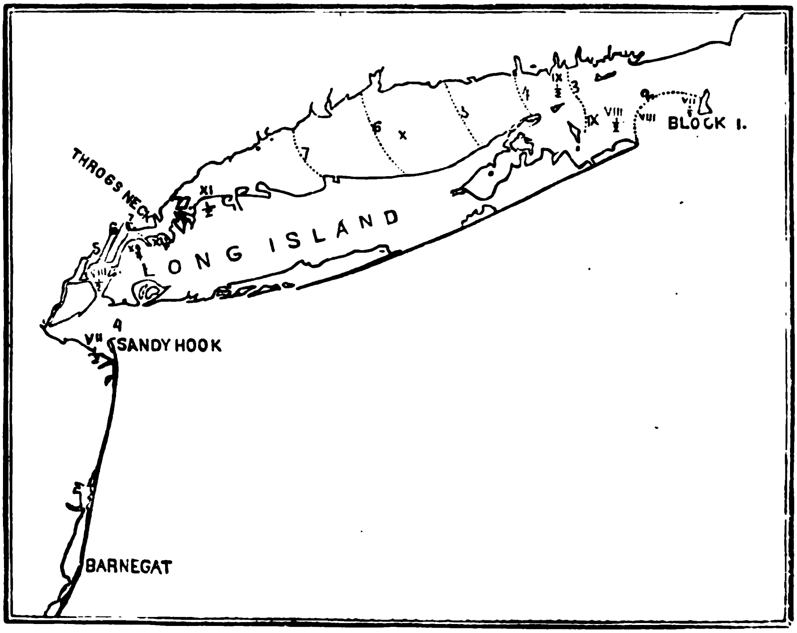


An interesting instance of this maintenance of the depth of channels from a determinate tidal basin is furnished by the effects of the obstructions placed in the channel over Charleston Bar during the war of the rebellion. On the accompanying diagram is seen the "stone fleet" sunk in the main channel, which at that time had twelve feet of water at low tide where the figure 7 indicates the present depth. There was, moreover, another channel, making out more to the southward, with nine feet of water, where the figure 3 indicates the present depth. The vessels were placed checker-wise, in such a manner as to impede navigation, while interfering least with the discharge of the water. The effect, nevertheless, was the formation of a shoal in a short time, and the scouring out of two channels, one on each side of the obstructions, through which twelve and fourteen feet can now be carried at low water. The increased water-way thus given to the ebb-tide caused it to abandon the old nine-foot channel on the less direct course to deep water. We have here the total obstruction of a channel which was of considerable importance to the southward trade by new conditions introduced at a point four miles distant from where the effect was produced, and we are warned how carefully all the conditions of the hydraulic system of a harbor must be investigated before undertaking to make any change in its natural conditions, lest totally unlooked-for results be produced at points not taken into consideration.

NEW YORK HARBOR.

Approaching now more closely to the consideration of the tidal conditions in New York Harbor, we will examine the progress of the tide-wave through Long Island Sound from the eastward to its meeting with that entering New York Bay at Sandy Hook.

TIMES AND HEIGHTS OF TIDES IN LONG ISD. SOUND AND NEW YORK HARBOR.



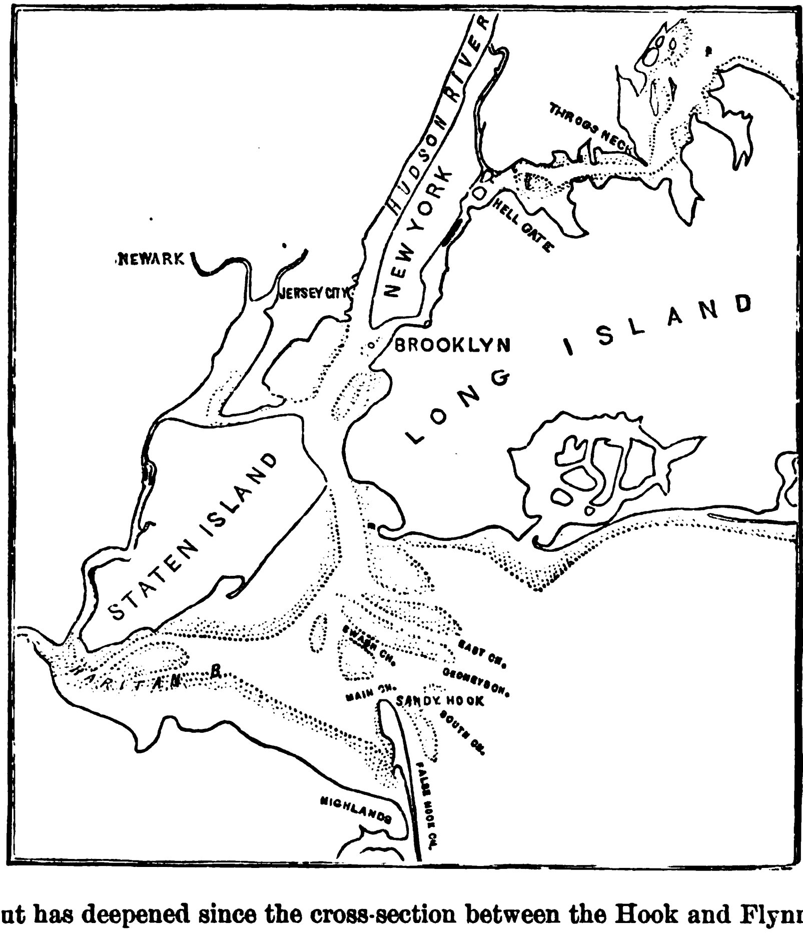
We see from the annexed diagram that about seven and a half hours after the transit of the moon high water has advanced just within Block Island with an elevation of two feet, and at the same time has just passed Sandy Hook with an elevation of four and a half feet. Traversing the sound at a rate indicated by the Roman figures, with increasing heights indicated by the Arabic numerals, it reaches Sand's Point eleven and a half hours after the transit of the moon with a height of seven and seven-tenths feet. The observed time of transmission from the Race to Sand's Point is two hours one minute, and the time computed from the depths, according to the law developed by Airy, is two hours fourteen minutes—a very good approximation, when we consider the irregularities in the configuration of the sound, which could not be taken into account. Advancing still farther, the height somewhat declines in consequence of the changes of direction in the channel and its shallowness. At Hell Gate this tide-wave is met by that which had entered at Sandy Hook, and advanced more slowly, owing to the narrowness and intricacies of the channel, especially in the East River.

These two tides, which meet and overlap each other at Hell Gate, differing from each other in times and heights, cause contrasts of water-elevations between the sound and harbor which call into existence the violent currents that traverse the East River. The conditions of the tidal circulation through Hell Gate are such, that if there were a partition across it, the water would sometimes stand nearly five feet higher, and at other times five feet lower, on one side than on the other. In the actual case of the superposition or compounding of the two tides the difference of level existing at any time is of course much less; but the difference of one foot is often observed within the space of 100 feet in the most contracted portion of Hell Gate, off Hallett's Point Referring now more particularly to the diagram representing New York Bay and Harbor, it is important to observe that the entrance from Long Island Sound is a natural depression or arm of the sea, which is not changed by the forces now in operation. The tidal currents which flow through it do not change the channel, but are obliged to follow it in its tortuous course. The Sandy Hook entrance, on the contrary, is characterized by a cordon of sands, extending from Sandy Hook to Coney Island, intersected by channels, which are maintained against the action of the sea, that tends to fill them up, by the scour of the ebb-tide from the tidal basin of New York Harbor.

Unlike Hell Gate passage, where permanence is the leading characteristic, the bar and channels of Sandy Hook have undergone continual changes within the brief period of our history. The advance of Sandy Hook upon the main ship-channel is among the notable and important instances of the effect of tidal currents. Within a century it has increased a mile and a quarter. In the place where the beacon on the end of the Hook now stands were forty feet of water fifteen years before it was built. The cause of this growth is a remarkably northwardly current along both shores of the Hook, running both during the flood and the ebb tides with varying rates, and resulting from those tides directly and indirectly.

The best water over the bar is about two miles east of Sandy Hook light, in a direct line with the swash channel, which is the second opening—shown on the sketch—above the Hook; the shoal lying between the main or Hook channel and the swash channel being known as Flynn's Knoll. The greatest depth over the bar is twenty-two feet at mean low water; and very nearly the same depth can now be carried through the swash channel, which formerly was three feet shallower,

ENTRANCE TO NEW YORK HARBOR



but has deepened since the cross-section between the Hook and Flynn's Knoll has been diminished by one-third its area by the growth of the Hook. This relative change in the capacity of the channels has not, however, affected the depth on the outer bar, which, according to the principles above laid down, is dependent mainly upon the area of the tidal basin within.

The depth of twenty-two feet at mean low water, which is now maintained at the entrance through the sands constantly thrown up by the waves of the sea, may be considered as depending upon the following elements:

1st. The large basin between Sandy Hook and Staten Island, including Raritan Bay, which furnishes more than one-half of the whole ebb-scour;

2d. What is called the Upper Bay, including the Jersey flats and Newark Bay;

3d. The North River, perhaps as far as Dobbs' Ferry, maintaining the head of the ebb-current, although not directly taking part in the outflow; and,

4th. A portion of the sound tide, which flows in through Hell Gate.

The proportion of the three first divisions in producing the depth of channel may be approximately estimated by a comparison of the areas and distances from the bar. In order to maintain the depth which we now have, it is important that the area of the tidal basin should not be encroached upon. In proportion as that is diminished the depth of the channels will decrease.

The flats, just bare at low water, but covered at high tide, form as important a part as any other portion, for it is obvious that it is only the volume of water contained between the planes of low and high water—the "tide-prism"—that does the work in scouring the channels. The water on the flats is especially useful by retarding the outflow, thus allowing a greater difference of level to be reached between the basin and the ocean.

When we yield to the demands of commerce any portion of the tidal territory to be used for its wharves and docks, we must do so with full cognizance of the sacrifice we are about to make in the depth of water over the bar; and in order to form any well-founded judgment in regard to the effect of such encroachments, it is necessary to be in possession of the fullest knowledge of all the physical facts involved in the problem, and no measure of encroachment should be determined upon except in pursuance of the advice of scientific experts.

A proposition frequently mooted by men of enterprise, and resisted by those interested in the welfare of the city of New York, is the occupation of the Jersey flats from Paulus Hook to Robbins Reef for docks and wharves. Without expressing any opinion as to the relative value of the gain of accommodation for shipping and the loss of depth in the channel, I venture to say that the withdrawal of that area from the domain of the tide would occasion a loss of not less than one foot in the depth of the bar off Sandy Hook, and certainly not more than two feet.

The part which the fourth division in our classification of the basin of New York, that of the East River and Hell Gate passage, plays in the outflow of the ebb-tide through the Sandy Hook channels, depends less upon the area involved than upon the difference in point of time and height of tide in Hell Gate, already adverted to. The westerly current, usually called the ebb-stream, since it falls in with the ebb-stream of New York Harbor, taking place when the sound-tide is highest, starts from a level of three and a half feet higher than the easterly, and thus a much larger amount of water flows out through the Sandy Hook channels than through the narrows at Throg's Neck. It is apparent, then, that this portion of the ebb-stream, re-enforcing as it does the ebb-stream of the harbor proper at the most favorable times, performs a most important part in maintaining the channels through the Sandy Hook bar. It may be estimated that the closing of Hell Gate would cause the loss of certainly not less than three feet in the depth of those channels.

From what has been said with regard to the meeting of the tides in Hell Gate, it will be seen that the violent currents experienced in that locality are due to causes beyond our control. The dangers to navigation arising from these currents, however, by their setting vessels upon the rocks and reefs, may, in a great measure, be done away with by the removal of the obstructions, in which work considerable progress has already been made. The removal of the reef at Hallett's Point, the work upon which is now in progress, will doubtless, in a great degree, do away with the eddies and under-currents produced by the sharp turn which the channel now takes at that point. It is not improbable that the successful removal of those obstructions will yet cause the sound entrance to be used in preference to the other by the fleets plying between European ports and the great commercial metropolis of America.

NOTE.—The reader who wishes to enter upon the mathematical treatment of the subject of tides is referred to Airy's treatise on tides and waves, and to the memoirs of Whewell and Lubbock, in the Philosophical Transactions of the Royal Society; and for investigations of the laws of the tides on our own coasts, to the papers on that subject by Bache and others in the annual reports of the Coast Survey. Among the latter, the lecturer is particularly indebted to the "Report on the tides and currents of Hell Gate," by Henry Mitchell, 1867, in which the complicated problem of the tidal circulation of New York Harbor is treated with great ability and success.

OBSERVATIONS UPON THE ELECTRICITY OF THE ATMOSPHERE AND THE AURORA BOREALIS, MADE DURING THE SWEDISH EXPEDITION OF 1868 TO THE NORTH POLE.

By Prof. Selim Lemström, *of the University of Helsingfors, Finland.*

There can be no *savant* now living who is not convinced that polar light is a phenomenon due to electric action in the upper regions of the atmosphere. Of the two theories which have been advanced to explain the phenomenon, one of which seeks its origin exclusively in variations in the intensity of terrestrial magnetism, the other in the electricity of the air, the former must give place to the latter, since there are very many convincing proofs in its favor. Unhappily, our knowledge of the electric state of the atmosphere in high polar regions is very limited; could it be extended, all doubts which now exist in regard to the subject would probably disappear. The attempts made to discover the nature of atmospheric electricity in the regions of the extreme north, have in general given only negative results, with the exception, however, of the researches made in the neighborhood of Bossekop by French *savants*, who, by sending up a kite or an arrow, attached by a conducting wire to an electroscope, to a vertical height of from 30 to 40 yards, have proved the constant presence of positive electricity; but, these observations are too few in number, and were made in a latitude not sufficiently high to be conclusive.

I. One of the most important of my objects in the physical researches of the expedition of 1868 was the study of the phenomena relating to the electricity of the atmosphere; but notwithstanding all my care, I obtained only negative results. As I am convinced that in every case I could account for my want of success, I will briefly describe the experiments I attempted, in order to pass to the observations I had occasion to make in regard to the aurora borealis.

The first experiment, made on the 26th and 28th of August, 1868, on a narrow tongue of land at Kobbe Bay, by means of the electrometer, gave no result, although the observations were made several times a day, and even at night, at the same time that I observed the magnetic instruments. Expecting to find the cause of these negative results either in the insensibility of the instrument or in the nature of the locality, which, closed on three sides by mountains, was open only on the side toward the sea, I determined to modify my instrument, and to look for a more open place for my observations. It was not until the 28th of September, while the Sophie was anchored at Southgatt, that I could carry this project into execution.

Having made my electrometer more sensitive, I went, on the day above mentioned, between 11 o'clock and noon, to an island situated at the mouth of the Southgatt, and established my instrument on the highest point of the island, 600 feet above the level of the sea. Notwithstanding these precautions I still obtained no certain result. This was possibly on account of the violence of the wind, which produced oscillations in the electrometer, but other observations made on the 7th of October at King's Bay were equally unsuccessful.

Although these experiments were too few in number, and too incomplete to draw from them any positive conclusion whatever, I am convinced that this absence of electric manifestation was due to the peculiar constitution of the air in these regions. A glance over the hygrometric observations shows that the air was almost constantly saturated with moisture, and this moisture did not exist merely in the form of insensible vapor, but also as fog. This circumstance rendered it almost impossible to isolate the instrument, and consequently to obtain the effects of the electricity of tension. We may at least conclude that there is no electricity of tension in northern aerial regions which approximate to a plain, but that the electricity rises through damp air into the higher regions of the atmosphere. I am inclined to believe that observations of the electricity of the air made on level ground will always give negative results. Elevated ground should be chosen, and an instrument which may be sent up into the higher strata of the atmosphere, such as the kite used by Franklin.

Setting aside these incomplete experiments, which can only be of use as guides for future efforts, I pass to the observations upon the aurora borealis.

During the last days of September the Sophie was anchored at Southgate, a strait lying between the island called Danes Island and the continent of Spitzbergen, at 79° 39′ 7″ of latitude and 11° 7′ of longitude west of Greenwich. The gulf of which this strait is an outlet is surrounded on the north and south by mountains, those on the south about 300 meters in height. At the mouth of this gulf lies the island above mentioned; to the east the view is limited by other mountains varying in height. The Sophie was anchored close to the shore of Danskow, a little to the northwest of the island, at the mouth of the strait. On returning from the island, where the instruments for the magnetic observations had been deposited, I perceived upon the ridge of the mountain, to the south, a brilliant polar light rising from 10° to 15° above the mountain in undulating rays, distinctly defined, at their base appearing as a diffuse yellowish light, but higher up as vertical orange beams, while at the top they formed a series of sharp points. The rays had an undulating motion, and the crest of the mountain was covered with a light fog, which the wind was moving from east-northeast to west-southwest. In a few moments the cloud of mist passed the mountain and the rays disappeared, but the crest of the mountain continued to be illuminated by a pale wandering light, which floated along the mountain, and of which it was not easy to determine the character; still I was in no doubt, for the spectral analysis very clearly displayed the yellow ray discovered in polar light by M. Angström. I continued to observe the crest of the mountain, over which foggy vapors were passing, allowing to appear from time to time the pale light I have described.

At 11 o'clock 30 minutes the upper part of the fog, which presented very much the appearance of a cloud with serrated edges, became illuminated with a yellowish white light, in the course of a moment converted into yellowish and reddish rays, which extended with an undulatory motion along the edges of the fog, following the irregularities in their minutest detail. The fog rose in the form of an arch about 10° above the mountain, and the rays attained a height of from 10° to 15°, which gives for the whole phenomenon an elevation of from 20° to 25° above the horizon. At the same time there began to appear at the north an indistinct combination of the brilliant edges of clouds, among which I clearly distinguished one, from which proceeded a distinctly-marked yellow ray, seeming in appearance to connect this cloud with another. The rest of the sky was covered with fillets or bands of light clouds, passing over the zenith from the east to the west and allowing the stars to appear at intervals.

The day following, the 26th of September, having observed the crest of the mountain with attention, I found it was almost entirely covered with snow, except at one or two places, which seemed to be those at which the night before the light had appeared with least intensity. The evening of the same day the phenomenon was again manifested, but with some modifications. A little below the horizon to the southwest, almost opposite the promontory or headland which terminates the mountain, appeared a series of clouds whose upper edges were strongly illuminated with a diffuse yellow and white light, which was very intense on the edge of the cloud at the extreme western end of the series, but diminished in brilliancy along the edges of the clouds until at the eastern end, where the last cloud seemed to melt into the headland, it was hardly perceptible. Very soon rays appeared, similar to those observed the night before, which seemed to proceed from a mist lying along the crest of the mountain, but somewhat back of it. This time the phenomenon seemed to take place at a much greater distance than during the preceding observations, but the form and color of the rays were the same; and I again, with the spectroscope, obtained the yellow ray as well from the light emanating from the edge of the clouds as from that proceeding from the rays themselves.

On the 27th of September, after having observed in the morning a radiation of yellowish-white light proceeding from one edge of a cloud which stood out prominently from a wall of clouds, I perceived in the evening, at 11 o'clock 30 minutes, a pale, wandering light moving distinctly along the ridge of the mountain. The light appeared for a few moments in the form of rays of a clear and brilliant yellow, following every detail of the sinuosities of the mountain. The pale glimmer of light seemed to follow the ridge of the mountain, and I was convinced, from the movement of the mists, that the luminous phenomenon was formed upon the ridge itself.

On the 30th of September, at 9h. 30 m., I witnessed on the island of Amsterdam a very intense luminous phenomenon, during which every peak and ridge, the most elevated, was illuminated with a pale light, particularly when covered with a vail of mist. We could clearly distinguish the contour of the mountains, and above them an effect of light, which frequently rose to a great height, and ended by gradually diminishing in intensity until lost in the upper strata of the mist. This light appeared during the whole of the harvest season, while we were stationed at Spitzbergen. Upon some peaks, overlooking a glacier which descends to the very bottom of Smeerenburg Bay, the light was still stronger. We even perceived upon one point reddish rays resembling flames, in which the spectroscope evidently indicated the presence of the yellow ray. On the days when this phenomenon was observed the wind was very strong, with a variable direction difficult to determine. We were, however, sure that there were two contending currents of air—the one from the north or east, the other from the south or west.

While the Sophie remained at Kingsbay, during the first fifteen days of October, every night fog-like mist covered the summits and ridges of the mountains, and their brilliancy seemed to increase as the season advanced. Besides this general phenomenon, we observed on the 9th of October, at 5h. in the morning, a brilliant polar light in the south, about 1,000 feet above the chain of mountains, which gradually faded away toward the north. A similar light appeared on the 11th of October and on the 12th, beneath a cloud upon the mountains, ready to be dissolved into snow, appeared a pale-yellow light with points at its edge. This luminous phenomenon had an undulatory movement, in addition to the forward motion given to it by the course of the clouds toward the west. Soon the light disappeared, and was replaced by a light fall of fine snow. On the 14th and 15th of October, in the evening, a cloud appeared, (on the 14th in the west-southwest, and on the 15th in the southeast, from the upper edge of which, when at a sufficient height above the horizon, emanated an intense yellow light, soon transformed into rays of genuine polar light, yellow at their base and red at the top. These rays, which moved with the cloud, rose with it nearly to the zenith, where they tended to form a crown.

On the entrance of the Sophie into the Norwegian archipelago, on the evening of the 18th of October, we saw some patches of polar light scattered here and there over the sky, in the north and east, which afterward formed a continuous ring around the horizon. The rays of this ring gradually elongated, and suddenly meeting around the zenith, formed for a few moments a boreal crown of perfect regularity and the most brilliant colors.

On our arrival at Tromsö, I examined with the spectroscope a beautiful polar light, which appeared on the 21st of October, commencing at the north. The first rays clearly displayed the yellow ray in question. The phenomenon becoming more brilliant, a variegated band was formed toward the south, of yellow, red, and green, which gave, 1st, the yellow ray; 2d, in the blue part, a very distinct and very clear ray; 3d, two lines of the breadth of a hair, showing very decided horizontal stripes by the side of the yellow. I ought to say that the yellow ray in every case seemed to me peculiar in being variable in intensity; sometimes more, sometimes less vivid. On the 27th of October, we were enabled to determine more accurately the position of the rays, and we found that the yellow line furnished by the yellow light of chloride of sodium was 61.0; in the auroral light, the yellow line was at 79.9; the blue at 65.90. The first of the shaded lines at 125.0; and the second shaded line at about 105.0.

II. Admitting, in general, the most of the opinions advanced in the work of M. Loomis, in regard to the aurora borealis,* which, in many respects, accord with the theory given by M. de la Rive, and supported by experiment, I have still, after the observations described, some doubts in regard to certain parts of this work, especially those which relate to the particular nature of the phenomenon.

The fact that polar light is an electric phenomenon, taking place in the atmosphere, is well established by the analogy which exists between its effects and those of electric currents. It produces, as they do, perturbations of the magnetic needle and currents in a good conductor. The luminous phenomenon itself exactly resembles the light produced by electric discharges in a damp atmosphere, or between two electrodes placed in rarified air. The results of spectral analysis, as well as those discovered by M. Angström, and the new rays I have described, give further proof of the electric origin of polar light; for, in order to obtain a spectrum with a gas, the latter must be incandescent, and electricity is the only source of heat which can produce this incandescence in the aerial molecules and other particles which constitute the atmosphere.

The question as to the height at which polar light is manifested has been the subject of much controversy. From observations made in America with great care and in several separate localities, M. Loomis calculated the height of the beautiful aurora borealis of the 2d of September to be at its lower limit 45 to 50 English miles, and at its upper limit from 400 to 500. Mr. Potter, in England, in 1833, gave, as height of the aurora, 63 miles, and Dalton, in 1826, estimated it at 100. During the French expedition, from 1838, 1839, observations made simultaneously at two stations—Bossekop and Jupwig—gave 60 to 100 miles as the height of the aurora. Polar light, however, has been often observed at much less height. Farquharson, by means of observations made at two distinct places, a mile apart, found a height of 2,481 English feet; and Captain Parry saw, on one occasion, polar light produced between the place where he was stationed and a mountain only about 3,000 yards distant. The French observations made at Bossekop equally proved the existence of polar light between the place of observation and a neighboring mountain.*

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* Smithsonian Report for 1865.

Although M. Loomis and M. Bravais himself believe that observations which give so low a height to polar light are erroneous, and the result of an illusion, I cannot agree with them, and I can offer in support of my opinion the phenomenon I observed on the 18th of October, 1868, at the entrance of the Norwegian archipelago, when the whole horizon was covered with rays, which were soon united around the magnetic pole, forming a regular crown. All the phenomena I have observed and described in regard to the illuminated edges of clouds, show very plainly that in these cases the polar light was produced in the region of clouds, and even lower. Moreover, we know by numerous observations that the number of storms accompanied by lightning and thunder diminishes considerably in proportion as we approach the polar regions, so that at 70° they no longer occur. Must we then conclude that in these regions the clouds are completely deprived of electricity? Certainly not, but only that the electrical discharges are made in some other way. I have on several occasions observed discharges, accompanied with electric light, proceeding from scattered clouds or banks of clouds such as produced true polar rays, and still more frequently I have seen the edges of clouds illuminated with a yellow light. But, however, in these high latitudes electricity is discharged not only by clouds, but also directly by damp air, as takes place in winter in the temperate zones. A great many direct observations prove the existence of slow discharges of this nature, and very remarkable confirmation is given of it by M. Angström, who on one occasion proved the presence of the yellow ray of polar light over almost the entire sky.

If it is well established that the phenomenon of polar light has its source in the electricity of the air, it follows that its appearance depends less upon terrestrial magnetism than has been hitherto supposed. This may exercise a direct action upon the discharge already produced, but cannot contribute to its production, which must depend upon certain conditions of the different strata of air. Although terrestrial magnetism has an influence upon the position of the luminous bow of polar light, it is difficult to believe, with Hansteen and Bravais, that the position of this bow is determined solely by the magnetic pole.

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*M. A. W. Malin, intendant of the Museum of Gottenburg, relates, in a description of a journey made in 1842 in the Laplands of Sweden and Norway, that, during an excursion from Maunu to Lyngen on the night of the 16th of March, he observed, at a height of 3,000 feet, with the temperature at 40 degrees below zero, a polar light between himself and the neighboring mountains, and heard a crackling sound which accompanied it.

The apex of the polar bow is rarely in the exact direction of the needle of declination. Of two hundred and twenty-six observations of the position of the azimuth of the luminous polar bow, 36 out of 100 placed it 30° more to the west, 32, 10° to 20°, 7, 0° to 10°, and 4, 0° to 26° to the east; from which it is evident that the position of the bow varies over a space of from 25 to 30° and more. These variations are very great to be explained by accidental perturbations in terrestrial magnetism, particularly as the greatest deviation in magnetic declination—that is, from 6° to about 7°—observed occasionally in polar regions is due to polar light itself.

We may then consider it certain that terrestrial magnetism relatively plays but a secondary part in the phenomenon of polar light; that this part essentially consists in a directive action upon the rays of this light, and in a rotary movement imparted to these rays—facts positively demonstrated by the experiments of M. de la Rive.

The formation of the auroral crown, which takes place when polar light is very intense and its rays are united around the magnetic zenith, is generally supposed to be an effect of perspective. When a certain number of polar rays, parallel to the direction of the needle of inclination, are projected to a considerable height, they ought to appear to unite around the magnetic zenith; but the aspect they present should be rather that of a lengthened point or a funnel, according as the observer is placed on one side or in the middle of the phenomenon. In polar regions it often happens that the polar rays start from all parts of the horizon, which is the case when the observer is within the ring. If then the crown was a phenomenon of perspective, the rays should appear to unite at a rather sharp angle. Now, this is by no means the case, for they form a vault, resembling very much the cupola of a church. Although my experience is not sufficient for me to make a positive assertion, I am strongly inclined to believe that, under the influence of terrestrial magnetism, and perhaps also through the effect of the conducting power of the medium, the rays of light undergo a flexion, the result of which is to unite them really, not merely in appearance, in the upper parts of the atmosphere. In proof I may cite the polar light I observed on the 18th of October, under the 17th degree of latitude. The rays starting from all parts of the horizon formed an immense ring, and united around the magnetic zenith, where the crown was formed in a perfectly regular manner, presenting the appearance of a flattened cupola. However, the experiments of M. de la Rive, which have demonstrated the influence of magnetism upon electric light, under circumstances almost identical with those presented by polar light, furnish no proof that the rays of this light are really united under this influence.

Polar light, considered as an electric discharge, produces the following results:*

1. An electric current, produced by the discharge itself, which takes place slowly.

2. Rays of light consisting of an infinite number of sparks, each spark giving rise to two currents of induction, proceeding in opposite directions.

3. An electric current, proceeding in an opposite direction from that of the charge, and originating in the electro-motive force, discovered by M. Edlund in the electric spark.

In order to develop these currents, a closed circuit is necessary. It is true that in the phenomenon of polar light this does not properly exist, but in that case the earth on one hand, and the rarefied air of the upper regions of the atmosphere on the other, are immense reservoirs of electricity, which produce the same effect as if the circuit was closed.

According to the theory of M. de la Rive, the positive electricity of the air, discharging itself into the ground, produces a current I will call principal; this current is re-enforced by one of the currents of induction, which M. Edlund has shown accompany the production of the electric spark; that is to say, the one which, going in the opposite direction from the charge, can alone acquire a certain degree of intensity. But this principal current thus re-enforced is counterbalanced in part by the one which has the contrary direction, and which produces the electro-motive force of the spark. We see by the observations made with telegraph wires during the appearance of polar light that it is sometimes the one, sometimes the other of these two currents which gains possession of the wire, the first being generally predominant, since it has been observed that the current given by telegraphic wires is more frequently directed from the north to the south than from the south to the north.

Under the circumstances which accompany the production of polar light, the latter contains in itself all the conditions necessary in order that magnetism may act upon it; for a ray of this light constitutes a current, flexible throughout, and consequently obedient to the law discovered by Plucker, according to which such a current necessarily takes the form of a magnetic curve. It is here we should look for the cause of the formation of the crown, taking at the same time into consideration the variations in conductibility of the rarefied air of the upper regions of the atmosphere.

When an arch of polar light appears, we consider that it forms part of a radiant ring, whose center coincides very nearly with the magnetic pole. The rays of this ring are parallel to the direction of the needle of inclination, and ought consequently to diverge from all sides; a circumstance unfavorable to their union in perspective at the magnetic zenith. But it is not proved that the radiation has always for center the magnetic pole; it may very well have another central point, as was the case during the observation I made on the 18th of October. On that occasion, in fact, the ring could not have been completely visible if it had had for center the magnetic pole. Besides, this variation of position is more in conformity with the manner in which the electric charges operate, and with the peculiarities observed in the local appearances of polar light.*

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* The author precedes this part of his work with the description of an experiment, in which he tried, but unsuccessfully, the action of a magnet upon a series of discharges produced by Holtz's machine under certain conditions. We omit this description, as it would be unintelligible without a figure to illustrate it, and it is not of great importance, since the results of the experiment were negative.

Returning to the lights observed around the elevated peaks of the Spitzbergen, I ought to say that this phenomenon has been noticed before. The learned philologist of Finland, Cashen, witnessed it in his journeys to Siberia, and his description of it exactly accords with what I have myself observed. Similar light has been seen in South America above the peaks of the Cordilleras, and in several other localities mentioned by M. Delleman. The *Archives des Sciences physiques et naturelles* (tome xxxi, p. 15) contain an article by M. H. de Saussure, in which are described a great number of phenomena, belonging, without doubt, to the same category. But it is in the arctic regions, above all others, that we find circumstances most favorable to observations of this kind, and it is much to be desired that future expeditions will undertake them.

If we seek for the reason why the clouds of the upper latitudes discharge themselves under the form of polar light, and not that of thunder and lightning, we find it in the *permanent humidity of the air.* The hygrometric observations, made during the expedition of the Sophie, show that the air is constantly saturated with aqueous vapors, which condense frequently into clouds, more rarely into rain. It is clear that this stratum of humidity, a good conductor of electricity, determines a slow discharge. If between the poles of an electrical machine, not sufficiently near together to produce a discharge, we project, by means of an atomizer, some water in spray, we see the discharge under the form of brilliant rays. It is the same in a glass cylinder in which the air has been rarified by several strokes of a piston, a rarefaction sufficient to produce a mist. The discharge, which at first appears as a spark, is gradually transformed into a luminous current, exhibiting the ordinary colors observed in polar light.

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*The author remarks here that the appearance of polar light is always accompanied by a dark segment, through which the stars are visible. He mentions in this connection the experiment of M. de la Rive, who, in transmitting the discharge of an induction coil through very rarefied air, proved the existence of a very remarkable dark band near the negative electrode. The author cites an experiment made by himself in the presence of M. Edlund, during which he obtained by means of an electrophorus, in a tube of very rarefied air, a bluish light, followed by a dark band strongly marked around the negative electrode, and a kind of crown of rays around the positive electrode. In the phenomenon of polar light, the earth constitutes the negative electrode, the rarefied air of the higher regions of the atmosphere the positive electrode, and the dark segment bears a strong resemblance to the dark band of the preceding experiment.

The more the relative degree of the humidity of the air increases an augmentation, which at the surface of the earth proceeds from the equator to the poles, the more easily the electric discharge acts under the form of polar light. But there may be a limit beyond which the humidity is so great that the discharge takes place without the accompaniment of light. Such would seem to be indicated by the table prepared by M. Loomis, of the geographical extension of polar light; according to which there must be a zone, comprised between the 68th and 76th degree of latitude in Europe, and between the 50th and 64th in America, in which the greatest number of phenomena of polar light are produced. This very interesting peculiarity has been proved by observations made during our expedition; at Spitzbergen the polar light always appeared to the south, while at a lower latitude, the 69th degree, it appeared at the zenith or to the north.

I now return to the question of spectral analysis; and for the moment notice only the mobility, so marked, of the light of the yellow ray, which seems to indicate a discontinuous luminous source which is evidently formed by an infinite number of sparks, succeeding each other in rapid succession.

As to the crackling or rattling noise which accompanies the appearance of polar light, I cannot say anything positively, since, on the occasions when I made my observations, the combined noise of the sea and the wind was of such a nature as to drown the faint crepitation of an electric discharge. It is very probable that such a noise can be heard under certain circumstances, for instance when the discharge takes place at a minimum height, and also when it is made between small particles of ice, which produce longer, and consequently stronger, sparks than those formed between particles of water. As these circumstances which are necessary for the production of this sound rarely occur, we can understand why observers do not agree in regard to the fact of its existence.

Some remarks upon the memoir of M. Lemström, by Professor De la Rive.

I find in the observations made by M. Lemström, in the polar regions, such a complete confirmation of the views I have expressed on several occasions in regard to the cause and explanation of polar auroras, that I cannot refrain from noticing very briefly some of the points upon which observation and theory completely agree. I have generally found myself in accord with observers, whether such as Parry, Franklin and Ross, or Bravais and Martins; it is rather between the theorists and myself that there has been occasionally some difference. I ought to thank M. Lemström for the pains he has taken, on every occasion, to mention my experiments, and the consequences I have deduced from them, the accuracy of which he has confirmed.

M. Lemström proves by a great number of facts, supported by incontestable reasoning, that polar light is due to atmospheric electricity, of which he has proved the presence in the polar regions, often in the region of clouds, and sometimes even nearer the earth. He shows, as I have done, that this light is the consequence of electric discharges, which in these regions, constantly pervaded with humidity, operate in a slow, continuous manner, instead of instantaneously by shocks producing lightning, as takes place in equatorial regions and middle latitudes.

He shows, with truth, that terrestrial magnetism, to which an exaggerated importance has been attributed, in the production of polar light, has only a very secondary part in this phenomenon. This part consists simply in giving to the luminous electric jets a certain direction they can follow because of their flexibility, which depends upon whether the medium through which they pass is gaseous. In support of his views in this respect, he refers to my experiments, by which I have demonstrated this influence, and the law by which, according to Plucker, it is governed.

One very essential point upon which M. Lemström insists, and which has been noticed by several observers, particularly by Bravais, is that the crown formed in some cases by the rays of polar light is very far from having always for center the magnetic zenith; that is to say, the vertical line passing through the magnetic pole of the earth. In fact, although the formation of this crown depends upon the directing influence of the magnetism upon the electric currents which form the luminous jets, and is not, as M. Lemström very well proves, a simple effect of perspective, it must also depend upon the direction of the passage of the electric discharges through the atmosphere, a direction which itself changes with the conductibility more or less variable of the different atmospheric strata, so that the united effect of these two influences ought to give to the rays a curvature and a position which cannot always be the same.

In short, the electric discharges which take place in the polar regions between the positive electricity of the atmosphere and the negative electricity of the terrestrial globe are the essential and only causes of the formation of polar light—light, whose existence is independent of that of terrestrial magnetism, which only imparts to it a certain direction, and in some cases a movement. These views I have always maintained in opposition to those who think they find in terrestrial magnetism, or rather, in the currents of induction which it can develop, the origin of polar light.

I will not dwell upon various interesting circumstances, such as the presence of a dark segment at the base of the luminous arcs of the aurora borealis, in which M. Lemström sees, as I do, an analogous effect to the dark band produced at the negative electrode, in electric discharges through rarified air; or such as the influence of particles of ice suspended in the atmosphere, which I have also noticed. I will confine myself to one point which, I confess, had completely escaped me, and which is of great importance. Although, in my theory, the terrestrial currents which result from the electric discharges, the cause of polar light, ought to be directed from the north to the south, some are observed, either in the telegraph-wires or in their action upon the needle of the compass, which have a contrary direction, that is from the south to the north. The former, it is true, are much the more numerous and the more intense; but still the latter are apparent from time to time. M. Lemström attributes them to the currents of induction, and the electro-motive force which accompanies always the production of an electric spark, as M. Edlund discovered. He considers in fact, and with reason, the electric discharges which constitute polar light, as a series of an infinite number of sparks, and in this fact found a satisfactory explanation of the existence of currents in an opposite direction from that of the principal current, which is from north to south.

The perusal of M. Lemström's article, while confirming me in the theoretical views I have advanced in regard to polar auroras, has shown me that there still remain many points to be explained of this interesting subject, especially in what concerns the propagation of electricity in air more or less damp, and reduced to a very low temperature and the influence of a very strong magnetism upon the electric discharges taking place under these conditions. I intend to pursue the subject with diligence.

ON A DOMINANT LANGUAGE FOR SCIENCE.

BY ALPHONSE DE CANDOLLE,
Of Geneva, Switzerland.[*]

At the period of the Renaissance, Latin was the language employed by all the learned men of Europe. It had been carefully preserved by the Romish Church; and not one of the modern languages presented, at that time, a sufficiently rich literature to become its rival. But at a later period the Reformation disturbed the unity of the Romish influence. Italian, Spanish, French, and English gained successively regular idioms, and became rich in literary productions of every kind; and at last, eighty or one hundred years ago at most, the progress of science caused the inconvenience of the use of Latin to be felt. It was a dead language, and, in addition to that, was wanting in clearness, owing to its inversions, to its abbreviated words, and to the absence of articles. There existed at that time a general desire to describe the numerous discoveries that were being made, and to explain and discuss them without the necessity of seeking for words. The almost universal pressure of these causes was the reason for the adoption of modern languages in most sciences, natural history being the only exception. For this, Latin is still employed, but only in descriptions—a special and technical part, where the number of words is limited and the construction very regular. Speaking truly, what naturalists have preserved is the Latin of Linnæus, a language in which every word is precise in meaning, every sentence arranged logically, clearly, and in a way employed by no Roman author. Linnæus was not a linguist. He knew but little even of modern languages, and it is evident that he struggled against many difficulties when he wrote in Latin. With a very limited vocabulary and a turn of mind which revolted equally from the periods of Cicero and the reticence of Tacitus, he knew how to create a language precise in its terms, appropriate to the description of forms, and intelligible to students. He never made use of a term without first defining it. To renounce this special language of the learned Swede would be to render descriptions less clear and less accessible to the *savants* of all nations. If we attempt to translate into the Latin of Linnæus certain sentences in modern floras, written in English or German, we quickly perceive a want of clearness. In English, the word *smooth* applies equally to *glaber* and

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[*] The fifth chapter of the Histoire des sciences et des savants depuis deux siècles, 8vo, Genève, 1873. London, Dulan. Translated by Miss Miers, by permission of the author. Ann. & Mag. N. Hist., ser. 4, vol. xi.

lævis.[*] In German, the construction of sentences indicating generic or other characters is sometimes so obscure that I have found it impossible, in certain cases, to have them put into Latin by a German, a good botanist, who was better acquainted than myself with both languages. It would be still worse if authors had not introduced many words purely Latin into their language. But, exclusive of paragraphs relative to characters, and wherever successive phenomena or theories are in question, the superiority of modern languages is unquestionable. It is on this account that, even in natural history, Latin is every day less employed.

The loss, however, of the link formerly established between scientific men of all countries has made itself felt. From this has arisen a very chimerical proposal to form some artificial language which should be to all nations what writing is to the Chinese. It was to be based on ideas—not words. The problem has remained quite devoid of solution; and even were it possible, it would be so complicated an affair—so impracticable and inflexible—that it would quickly drop into disuse.

The wants and the circumstances of each epoch have brought about a preference for one or other of the principal European languages as a means of communication between enlightened men of all countries. French rendered this service during two centuries. At present various causes have modified the use of this language in other countries, and the habit has been almost everywhere introduced that each nation should employ its own tongue. We have, therefore, entered upon a period of confusion. What is thought to be new in one country is not so to those who read books in other languages. It is vain to study living languages more and more; you are always behindhand in the complete knowledge of what is being published in other countries. Few persons are acquainted with more than two languages; and if we try to pass beyond a certain limit in this respect, we rob ourselves of time for other things; for there is a point at which the study of the means of knowledge hinders our learning. Polyglot discussions and conversations do not answer the intentions of those who attempt them. I am persuaded that the inconvenience of such a state of things will be more and more felt. I also believe, judging by the example of Greek as used by the Romans and French in modern times, that the need of a prevailing language is almost always recognized; it is returned to from necessity after each period of anarchy. To understand this we must consider the causes which make a language preferable, and those which spread its employment in spite of any defects it may possess.

Thus, in the seventeenth and eighteenth centuries, motives existed for the employment of French in preference to Latin throughout Europe. It was a language spoken by the greater part of the educated men of the period—a language tolerably simple and very clear. It had an advantage in its resemblance to Latin, which was then widely known. An Englishman, a German, was already half acquainted with French through his knowledge of Latin; a Spaniard, an Italian, was three parts advanced in his study of the language. If a discussion were sustained in French, if books were written or translations made in this language, all the world understood.

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[*] The word *glaber*, in botany, means bald or not hairy, which is applied to other parts as well as the head; and *lævis*, smooth, not rough; but I know they have both been carelessly translated "smooth," as M. de Candolle implies.—J. E. G.

In the present century, civilization has much extended north of France, and population has increased there more than to the south. The use of the English tongue has been doubled by its extension into America. The sciences are more and more cultivated in Germany, in England, in the Scandinavian countries, and Russia. The scientific center of gravity has advanced from the south toward the north.

Under the influence of these new conditions, a language can only become predominant by presenting two characters: first, it must possess sufficient German and Latin words or forms to be within reach at once of the Germans and of the people who make use of Latin tongues; secondly, it must be spoken by a considerable majority of civilized people. In addition to these two essential conditions, it would be well for the definitive success of a language that it should also possess the qualities of grammatical simplicity, of conciseness, and clearness.

English is the only language which may, in fifty or a hundred years offer all these conditions united.

The language is half German and half Latin. It possesses German, words, German forms, and also French words, and a French method of constructing sentences. It is a transition between the principal languages used at present in science, as French was formerly between Latin and several of the modern languages.

The future extension of the Anglo-American tongue is evident. It will be rendered inevitable by the movement of the populations in the two hemispheres. Here is the proof, which it is easy to give in a few words and a few figures.

At the present time the population stands thus, (Almanach de Gotha, 1871:*)

English-speaking peoples in England, 31,000,000; in the United States, 40,000,000; in Canada, &c., 4,000,000; in Australia and New Zealand, 2,000,000; total, 77,000,000.

German-speaking peoples in Germany and a portion of Austria, 60,000,000; in Switzerland, (German cantons,) 2,000,000; total, 62,000,000.

French-speaking peoples in France, 36,500,000; in Belgium, (French portion,) 2,500,000; in Switzerland, (French cantons,) 500,000; in Algeria and the colonies, 1,000,000; total 40,500,000.

Now, judging by the increase that has taken place in the present century, we may estimate the probable growth of population as follows: †

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* No notice is here taken of the English-speaking people in India and the East.—J. E. G.

† Almanach de Gotha, 1870, p. 1039.

In England it doubles in fifty years; therefore, in a century (in 1970) it will be 124,000,000. In the United States, in Canada, in Australia, it doubles in twenty-five; therefore it will be 736,000,000. Probable total of the English-speaking race in 1970, 860,000,000.

In Germany the northern population doubles in fifty-six to sixty years; that of the south in one hundred and sixty-seven years. Let us suppose one hundred years for the average. It will probably be, in 1970, for the countries of German speech, about 124,000,000.

In the French-speaking countries the population doubles in about one hundred and forty years. In 1970, therefore, it will probably amount to 69,500,000.

Thus the three principal languages spoken at the present time will be spoken a century hence with the following progression:

The English tongue will have increased from 77 to 860 millions.

The German tongue will have increased from 62 to 124 millions.

The French tongue will have increased from 40½ to 69½ millions.

The individuals speaking German will form a seventh part, and those speaking French a twelfth or thirteenth part of those of English tongue; and both together will not form a quarter of the individuals speaking English. The German or French countries will then stand toward those of English speech as Holland or Sweden do at present with regard to themselves. I am far from having exaggerated the growth of the Anglo-Australian-American populations. Judging by the surface of the countries they occupy, they will long continue to multiply in large proportion. The English language is, besides, more diffused than any other throughout Africa and Southern Asia. America and Australia are not, I confess, countries in which the culture of letters and sciences is so much advanced as in Europe; and it is probable that, for a length of time, agriculture, commerce, and industry will absorb all the most active energies. I acknowledge this. But it is no less a fact that so considerable a mass of intelligent and educated men will weigh decisively on the world in general. These new peoples, English in origin, are mingled with a German element, which, in regard to intellectual inclinations, counterbalances the Irish. They have generally a great eagerness for learning and for the application of discoveries. They read much. Works written in English or translated into that tongue would, in a vast population, have a very large sale. This would be an encouragement for authors and translators that is offered by neither the French nor the German language. We know in Europe to what degree difficulties exist in the publication of books on serious subjects; but open an immense mart to publishers, and works on the most special subjects will have a sale. When translations are read by ten times as many people as at present, it is evident that a greater number of books will be translated; and this will contribute in no small degree toward the preponderance of the English language. Many French people already buy English translations of German books, just as Italians buy translations in French. If English or American publishers would adopt the idea of having translations made into their language of the best works that appear in Russian, Swedish, Danish, Dutch, &c., they would satisfy a public dispersed over the whole world, and particularly the numerous Germans who understand English. Yet we are but at the beginning of the numerical preponderance of the English-speaking populations.

The nature of a language does not, at first sight, appear to have very great influence on its diffusion. French was preferred for two centuries; and yet Italian was quite as clear, more elegant, more harmonious, had more affinity with Latin, and, for a length of time, had possessed a remarkable literature. The number, the activity of the French, and the geographical position of their country were the causes of their preponderance. Yet the qualities of a language, especially those preferred by the moderns, are not without their influence. At the present time briefness, clearness, grammatical simplicity are admired. Nations, at least those of our Indo-European race, began by speaking in an obscure, complicated manner; in advancing they have simplified and made their language more precise. Sanscrit and Basque, two very ancient languages, are exceedingly complicated. Greek and Latin are so in less degree. The languages derived from Latin are clothed in clearer and simpler forms. I do not know how philosophers explain the phenomenon of the complication of language at an ancient period; but it is unquestionable. It is more easy to understand the subsequent simplifications. When a more easy and convenient method of acting or speaking has been arrived at, it is naturally preferred. Besides, civilization encourages individual activity; and this necessitates short words and short sentences. The progress of the sciences, the frequent contact of persons speaking different languages, and who find a difficulty in understanding each other, lead to a more and more imperious need for clearness. You must have received a classical education to avoid the perception of absurdity in the construction of an ode of Horace. Translate it literally to an uneducated workman, keeping each word in its place, and it will have to him the effect of a building the entrance-door of which is on the third story. It is no longer a possible language, even in poetry.

Modern languages have not all, to the same degree, the advantages now demanded, of clearness, simplicity, and briefness.

The French language has shorter words and less complicated verbs than the Italian; this in all probability has contributed to its success. The German has not undergone the modern revolution by which each sentence or portion of a sentence begins with the principal word. Words are also cut in two, and the fragments dispersed. It has three genders, whereas French and Italian have but two. The conjugations of many verbs are rather complicated. Nevertheless, modern tendencies weigh with the Germans, and it is evident that their language is becoming a little modified. Scientific authors especially exert themselves to attempt the direct modes of expression and the short phrases of other countries in the same way that they have abandoned the Gothic printed letters. Should they correspond with strangers, they often have the politeness to write in Latin characters. They willingly introduce in their publications terms taken from foreign languages, modifications sometimes merely of form, occasionally fundamental. These attest the modern spirit and the enlightened judgment of the learned men so numerous in Germany. Unhappily, the modifications of form have no great importance, and the fundamental changes take place very slowly.

The more practical English language shortens sentences and words. It willingly takes possession of foreign words, as German does; but of *cabriolet* it makes *cab;* of *memorandum* it makes *mem.* It makes use only of indispensable and natural tenses—the present, the past, the future, and the conditional. There is no arbitrary distinction of genders; animated objects are masculine or feminine; the others are neuter. The ordinary construction is so sure to begin with the principal idea, that in conversation you may often dispense with the necessity of finishing your sentences. The chief fault of the English language, its inferiority in comparison with German or Italian, consists in an orthography absolutely irregular, and so absurd that children take a whole year in learning to read.* The pronunciation is not well articulated, not well defined. I shall not go as far as Madame Sand in her amusing imprecations on this point; but there is truth in what she says. The vowels are not distinct enough. But, in spite of these faults, English, according to the same clever writer, is a well-expressed language, quite as clear as any other, at least when English people choose to revise their MMS., which they will not always do, they are in such a hurry!

English terms are adapted to modern wants. Do you wish to hail a vessel, to cry "stop" to a train, to explain a machine, to demonstrate an experiment in physics, to speak in few words to busy and practical people, it is the language *par excellence.* In comparison with Italian, with French, and, above all, with German, English has the effect, to those who speak several languages, of offering the shortest cut from one point to another. I have observed this in families where two languages are equally well known, which often occurs in Switzerland. When the two languages are German and French, the latter almost always carries the day. "Why?" I asked of a German-Swiss established in Geneva. "I can scarcely tell you," he replied; "at home we speak German to exercise my son in the languages, but he always falls back into the French of his comrades. French is shorter—more convenient." Before the events of 1870, a great Alsatian manufacturer sent his son to study at Zürich. I was curious to know the reason why. "We cannot," he said, "induce our children to speak German, with which they are quite as familiar as with French. I have sent my son to a town where nothing but German is spoken, in order that he may be forced to speak it." In such preferences you must not look for the causes in sentiment or fancy. When a man has choice of two roads—one straight and open, the other crooked and difficult to find—he is sure to take, almost without reflection, the shorter and more convenient one. I have also observed families where the two languages known in the same degree were English and French. In this case the English maintained supremacy, even in a French-speaking land. It is handed down from one generation to another. It is employed by those who are in haste, or who want to say something in as few words as possible. The tenacity of French or English families established in Germany in speaking their own language, and the rapid disappearance of German in the German families established in French or English countries, may be explained by the nature of the languages rather than by the influence of fashion or education.

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* Surprised, on one occasion, by the slowness with which intelligent English children learned reading, I inquired the reason. Each letter has several sounds, or you may say that each sound is written in several ways. It is therefore necessary to learn reading word for word. It is an affair of memory.

The general rule is this: In the conflict of two languages, everything else being equal, it is the most concise and the most simple that conquers. French beats Italian and German. English beats the other languages. In short, it need only be said that the more simple a language is, the more easy it is to be learned, and the more quickly can it be made available for profitable employment.

The English language has another advantage in family use—its literature is the one most suitable to feminine tastes; and every one knows how great is the influence of mothers on the language of children. Not only do they teach what is called "the mother tongue," but often, when well educated, they feel pleasure in speaking a foreign language to their children. They do so gayly, gracefully. The young lad who finds his language-master heavy, his grammar tiresome, thinks very differently when his mother, his sister, or his sister's friend addresses herself to him in some foreign tongue. This will often be English, and for the best of reasons: there is no language so rich in works (written in a spirit of true morality) upon subjects which are interesting to women—religion, education, fiction, biography, poetry, &c.

The future preponderance of the language spoken by English, Australians, and Americans thus appears to me assured. The force of circumstances leads to this result; and the nature of the language itself must accelerate the movement.

The nations who speak the English tongue are thus burdened with a responsibility which it is well they should recognize at once. It is a moral responsibility toward the civilized world of the coming centuries. Their duty, as it is also their interest, is to maintain the present unity of the language, at the same time admitting the necessary or convenient modifications which may arise under the influence of eminent writers, or be arranged by common consent. The danger to be feared is that the English language may, before another century has passed, be broken up into three languages, which would be in the same relation to each other as are Italian, Spanish, and Portuguese, or as Swedish and Danish. [*]

Some English authors have a mania for making new words. Dickens has invented several. Yet the English language already possesses many more words than the French, and the history of its literature shows that there is greater need to suppress than to add to the vocabulary. No writer for three centuries past has employed nearly so many different words as Shakespeare; therefore there must have been many unnecessary ones. Probably every idea and every object had formerly a term of Saxon origin, and one of Latin or French origin, without counting Celtic or Danish words. The very logical operation of time has been to suppress the double or triple words. Why re-establish them? A people so economical in its use of words does not require more than one term for each thing.[*]

The Americans, on the other hand, make innovations of accent or orthography, (they almost always spell *labour* "labor," and *harbour* "harbor.") The Australians will do the same if they do not take care. Why should not all possess the noble ambition of giving to the world one uniform concise language, supported by an immense literature, and spoken in the next century by eight hundred or one thousand millions of civilized men? To other languages it would be as a vast mirror, in which each would become reflected, thanks to newspapers and translations, and all the friends of intellectual culture would have a convenient medium for the interchange of ideas. It would be rendering an immense service to future races, and at the same time the authors and men of science of English-speaking race would give a strong impulsion to their own ideas. The Americans, above all, are interested in this stability, since their country is to be the most important of those of English tongue. How can they acquire a greater influence over Old England than by speaking her language with exactness?

The liberty of action permitted among people of English race adds to the danger of a division in the language. Happily, however, certain causes which broke up the Latin language do not exist for English nations. The Romans conquered nations the idioms of which were maintained or re-appeared here and there in spite of administrative unity. The Americans and Australians, on the contrary, have before them only savages, who disappear without leaving any trace. The Romans were conquered and dismembered in their turn by the barbarians. Of their ancient civilization no evidence of unity remained, unless it was in the Church, which has itself felt the influence of the universal decline. The Americans and Australians possess many flourishing schools; they have the literature of England as well as their own. If they choose, they can wield their influence by means of maintaining the unity of the language. Certain circumstances make it possible for them to do so; thus the teachers and professors mostly come from the States of New England. If these influential men truly comprehend the destiny of their country, they will use every effort to transmit the language in its purity; they will follow classic authors, and discard local innovations and expressions. In this question of language, real patriotism (or, if you will, the patriotism of Americans really ambitious for their country) ought to be, to speak the English of Old England, to imitate the pronunciation of the English, and to follow their whimsical orthography until changed by themselves. Should they obtain this of their countrymen, they would render to all nations and to their own an unquestionable benefit for futurity.

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[*] A clever English writer has just published a volume on the institutions of the people called *Swiss* in English. He names them *Switzers*. For what reason? Will there soon be *Deutschers*?

The example of England proves the influence of education upon the unity of a language. It is the habitual contact of educated people and the perusal of the same books which, little by little, is causing the disappearance of Scotch words and accent. A few years more, and the language will be uniform throughout Great Britain. The principal newspapers, edited by able men, also exercise a happy influence in preserving unity. Whole columns of the "Times" are written in the language of Macaulay and Bulwer, and are read by millions of people. The result is an impression which maintains the public mind in a proper literary attitude.

In America the newspaper articles are not so well written; but the schools are accessible to all classes, and the universities count among their professors men especially accomplished in their use of the English tongue. If ever there should arise a doubt in the opinions of the two countries as to the advisability of modifying the orthography, or even making changes in the language, it would be an excellent plan to organize a meeting of delegates from the principal universities of the Three Kingdoms, of America, and Australia, to propose and discuss such changes. Doubtless they would have the good sense to make as few innovations as possible; and, thanks to common consent, the advice would probably be followed. A few modifications in the orthography alone would render the English language more easy to strangers, and would contribute toward the maintenance of unity in pronunciation throughout Anglo-American countries.

NOTES BY DR. JOHN EDWARD GRAY, OF THE BRITISH MUSEUM.

It may be observed, in addition, that the people who use the English language in different parts of the world are a reading and a book-buying people, and especially given to the study of quasi-scientific books, as is proved by the fact of the extensive sale which they command.

In support of this assertion, I may quote the Baron Férussac's review of Wood's "Index Testaceologicus," in the Bull. Sci. Nat., Paris, 1829, p. 375. He remarks:

"We observe with interest the number of subscribers that exist in England for an octavo volume on shells, costing 186 francs. It is a curious fact, which booksellers and authors will appreciate, as it will afford them the means of seeing how a return is obtained for their outlay on such works in England, compared with other countries. The number of subscribers is 280, of which 34 are females and 6 foreigners. Certainly all the rest of Europe could not produce as many, nor perhaps even the half of that number."

How much more astonished would M. Férussac have been, if informed that these were only the subscribers before publication, and that 1,000 copies were sold! Since 1829 the sale of scientific books has much increased, as is shown, for example, by the many editions of the works of Lyell and other naturalists, each edition being of 1,000 copies.

Most scientific books in France and other continental countries can only be published when the government furnishes the cost; and they are chiefly published in an expensive form as a national display, and are almost confined to their public libraries, except the sale of copies that are bought by English collectors.

In England such works are generally published by individual enterprise, and depend on the general public for their support, and are published in a style to suit the different classes. Thus there are works of luxury for the rich, often published by individuals who confine themselves to the production of that class of books; very cheap works for the student and mechanic; and books of all intermediate grades, produced by the regular publishers. The females of all grades are extensive readers of this class of books, which, I believe, is chiefly the case with English-speaking races.

Some of the scientific Swedes and Russians have published their papers in the English language, or appended an abstract in English to them, as Thorell on European Spiders; Professor Lilljeborg on *Lysianassa*, and Professor Wackerbarth on the Planet Leda, &c. The Danes and Dutch often publish *their* scientific papers in French, as Temminck, Reinhardt, and the late Professor Van der Hoeven, who themselves read and write English; but it appears they regard French as the polite language of courts, and forget that courtiers, generally, have a contempt for science, and that they should look among the people for their readers.

It is to be observed that Professor de Candolle himself uses the French language with a very English construction; but we believe that his work would have commanded the greatest number of readers if written in the English language, which he reads and writes so fluently.

See, also, Mr. Galton's interesting article on the Causes which create Scientific Men, in the "Fortnightly Review" for March, 1873, p. 346, which contains some interesting observations on M. de Candolle's work.

ON UNDERGROUND TEMPERATURE.

Prepared for the Smithsonian Institution by CHARLES A. SCHOTT, of the U. S. Coast Survey.

The earth's solid crust being hotter than the mean temperature of the lower atmosphere resting on its surface, heat is constantly and very slowly passing outward, and strata of equal depth would have very nearly uniform temperatures but for the influence of the daily, the annual, and the irregular variations of the atmospheric temperature, received by conduction. The solar heat then acts as a disturbance of the thermal equilibrium, and the depth of the stratum of the so-called "invariable temperature," *i. e.*, when the changes escape ordinary observation or become less than 0°. 01 C., as generally defined, is found about 6 meters below the surface in the tropics, and about 30 meters below the surface in the middle latitudes. The corresponding depths at which the *daily* variations become imperceptible are 0.3 meter and 1.3 meter very nearly. These numbers, however, depend greatly on the kind of soil or rock, and will differ considerably for loose soil of greater or less porosity and for solid rock. Our records of observations are very scanty and deficient in range, and barely afford the necessary data to form a basis of calculation, on account of the many conditions which enter into the problem.

It would appear from experience that the mean temperature of the air, as ordinarily observed, say at an elevation of 1 or 2 meters above ground, is slightly higher than the mean temperature of the surface of the soil. The mean temperature of the earth's crust increases from the surface, with increasing depth, and with a nearly uniform rate for moderate depths, with an average amount of about 28 meters for each degree of the centigrade scale, and the temperature at the depth of invariable heat nearly equals the mean annual atmospheric temperature of the place, but slightly exceeds it in amount. For greater depths the descent to produce an increase of 1° C. is *greater* than the amount given above. With increase of depth the amplitude of change is rapidly diminishing, and for a depth increasing arithmetically the amplitudes diminish in geometrical ratio; also the depth at which the daily and annual variations, respectively, disappear is in proportion of the square root of the length of these periods, or about 1 to 19. The amplitude Δp has been represented in the form, $\log \Delta p = A - Bp$, where A and B are constants to be determined at the place, and p the depth. Observations by Quetelet at Brussels, for instance, give the following result: $\log \Delta p = 1.15108 - 0.04149p$, (amplitude in degrees centigrade and p in feet.) At this place the following mean temperatures and epochs of maxima have been obtained:

Depth in feet.	Mean temperature.	Epochs of maxima.	Depth in feet.	Mean temperature.	Epochs of maxima.
	° C.		° C.		
0.00	......	July 20.	3.08	11.03	August 10.
0.58	9.82	July 25.	6.00	11.61	September 6.
1.38	10.17	August 2.	12.00	12.05	October 9.
2.31	10.56	August 7.	24.00	12.06	December 12.

At Edinburgh the following results were obtained:

Depth in meters.	Mean temperature.	Amplitude.	Depth in meters.	Mean temperature.	Amplitude.
	° C.	° C.		° C.	° C.
0.91	7.93	8.3	3.66	8.30	2.8
1.83	8.08	5.6	7.32	8.47	0.6

For the greatest depth, the time required for the heat-wave to reach it is nearly six months, making the surface maximum temperature coincident with the minimum temperature of the stratum, 7.32 meters below.

In the case of Chicago, we may take the mean annual temperature of the atmosphere just above the surface=8°.17 C.; that of the surface of the soil=8°.0 C. The increase for a depth of 12.2 meters for the lowest stratum of clay and to the rock-surface will be 0°.44 C., making 8°.44 C. for this depth. The invariable temperature may be estimated about 9 or 10 C., and may be found at a depth between 30 and 40 meters, the variations being transmitted to a greater depth in rock than in clay. At the surface of the rock the variations of temperature will probably yet amount to 0°.1, (according to the Edinburgh observations.) For a depth of 229 meters, corresponding to the depth from which the well-water flows, the increase of heat should amount to 8°.2 C., according to the mean given above; hence the computed temperature 16°.2 C. But the observed temperature is only 12°.8 C., showing either a much slower rate of increase (1° C. in 48 meters) or a local deviation, probably due to infiltration of water from a higher level. Whether the lake-water, which is colder at the same depth than solid matter would be, can exert an influence by conduction, I do not know.

Prof. J. D. Everett, chairman of the committee of the British Association for the Advancement of Science, on the subject of underground temperature has published a number of valuable reports The following is an extract from a recent communication of his to the Belfast Natural History and Philosophical Society:

"The phenomena of underground temperature may conveniently be classed under two heads, according as attention is directed to the first forty or fifty feet, or to such depths as are attained in mines and artesian wells.

"The annual wave of temperature is propagated downward from the surface, at a rate which depends on the nature of the soil, and is on the average rather greater than a foot per week; while at the same time the amplitude (or magnitude) of the wave diminishes in a ratio also dependent on the soil, and amounting on the average to a halving of the amplitude for every five or six feet of descent.

"Supposing the soil to be uniform, the surface to be plane, and the propagation of heat to be effected solely by conduction, a simple harmonic variation of temperature at the surface (which we may call in popular language a simple wave of temperature) will be propagated downward with a uniform velocity, and with amplitude diminishing in geometrical progression. There will, moreover, be a definite relation between the ratio of this progression and the velocity of propagation, so that if the one is given the other can be computed. In fact, we shall have—

$$2\pi \times \frac{\text{time of propagation from one depth to another}}{\text{period of variation}}$$

$$= \text{Napierian logarithm of } \frac{\text{amplitude at 1st depth}}{\text{amplitude at 2d depth}}$$

$$= \frac{\text{difference of depths}}{\sqrt{\text{period of variation}}}\sqrt{\frac{\pi c}{k}} \, .$$

where π denotes 3.1416; c, thermal capacity per unit-volume; and, k, conductivity.*

"If the variation of temperature at the surface, instead of being simple harmonic, be any periodic variation whatever, it can be reduced by Fourier's method to the sum of a number of simple harmonic variations, and each of these variations will be propagated according to the above law, unaffected by the rest.

"As the square root of the number of days in the year is almost exactly 19, the above formula shows that the annual wave is propagated 19 times as fast as the diurnal wave, and that the falling-off in amplitude is the same in one foot for the diurnal wave as in 19 feet for the annual wave.

"Of the different simple harmonic components which make up the whole variation at the surface, those of longest period are propagated downward most quickly, and die away most slowly. For this reason,

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* The numerical value of the co-efficient $\sqrt{\frac{\pi c}{k}}$, as given in Professor Everett's Discussion of the Observations at the Greenwich Observatory, 1860, is as follows:

From the Greenwich observations	0.0918
From Calton Hill, trap-rock	0.1156
From Experimental Garden, sand	0.1098
From Craigleith Quarry, sandstone	0.0674

The diminution of $\sqrt{\frac{\pi c}{k}}$ indicates either a decrease in capacity for heat or an increase in conductivity.

as well as from its greater original magnitude, the annual simple harmonic wave becomes more and more predominant as we descend, and the curve of temperature for the year approaches more and more nearly to the form of a simple harmonic curve, or curve of sines.

"Observations taken at three stations in or near Edinburgh, and at Greenwich Observatory, have been reduced in accordance with the above principles, the result being in every case to show a satisfactory agreement between theory and practice; and the values of the thermal coefficient $\frac{c}{k}$ thus obtained for these four stations, have furnished the basis of the most reliable calculations yet made regarding the earth's age as a habitable globe. For the three Edinburgh stations the value of c (which is the product of specific heat by specific gravity) was also determined by laboratory experiments conducted by Regnault, and hence the conductivity, k, was found by computation.

"The following is a sample of the temperatures observed at Greenwich at the depths of 1 inch, 12.8 feet, and 25.6 feet. The warmest and coldest calendar months had the following mean temperatures:

	Warmest.	Mean temp.	Coldest.	Mean temp.
1 inch	July	65.9	January	40.5
3 feet	August	62.5	February	41.1
12.8 feet	September	55.5	April	46.1
25.6 feet	November	52.0	June	48.6

"The mean temperature at a depth of 10, 20, or 30 feet does not differ much from the mean temperature at the surface. A slight increase is, however, usually observable even at these small depths; and, when we penetrate to the depth of several hundred feet, we find the temperature higher by several degrees than the mean temperature of the surface. In fact, the deeper we go the higher is the temperature which we find.

"Attempts were formerly made to explain away this phenomenon, the high temperatures observed in deep mines being ascribed to the presence of the men working in them, assisted in some cases by the slow combustion of pyrites; but the fact of a steady increase downward, at a rate which is not exactly uniform, but varies from about 1° Fahr. in 100 feet to 1° Fahr. in 40 feet, has now been placed beyond all question."

Theoretical investigations will be found in Fourier's Théorie analytique de la chaleur, Paris, 1822; in Poisson's Traité mathématique de la chaleur, Paris, 1835. See also various papers by Quetelet in the Mém. de l'Acad. roy. de Bruxelles; also, Piazzi Smyth in Astronomical Observations at the Royal Observatory at Edinburgh; Forbes and his own Observations, vol. xi, for 1849–'54, and vol. xiii, for 1860–'70. A fair statement of the subject is found in Schmid's Meteorology, Leipsic, 1860. See, also, J. D. Forbes's "Experiments on the Temperature of the Earth," in Trans. R. S. E., 1846; Sir W. Thomson "On the Reduction of Observations of Underground Temperature," in Trans. R. S. E., 1860; "On the Age of the Sun's Heat," in Macmillan's Magazine, March, 1862; "On the Secular Cooling of the Earth," in Trans. R. S. E., 1862, (reprinted at the end of Thomson and Tait's "Treatise on Natural Philosophy;") "The Doctrine of Uniformity in Geology Briefly Refuted," in Proc. R. S. E., December, 1865; "On Geological Time," in Trans. Geol. Soc., Glasgow, vol. III, part I; "Of Geological Dynamics," in Trans. Geol. Soc., Glasgow, vol. III, part II; J. D. Everett "On a Method of Reducing Observations of Underground Temperature," in Trans. R. S. E., 1860; "On the Mean Temperature of a Stratum of Soil," in Trans. R. S. E., 1862; "Reduction of the Observations of the Deep-sunk Thermometers," in Greenwich Observations, 1860; "Reports of Committee on Rate of Increase of Underground Temperature," in B. A. Reports, from 1868 onward.

ON A SERIES OF EARTHQUAKES IN NORTH CAROLINA, COMMENCING ON THE 10TH OF FEBRUARY, 1874.

By Professor Warren du Pré,
Of Wofford College, Spartanburgh, S. C.

The following is an extract from a letter of the 24th April, 1874, from Professor Du Pré to General Benjamin Alvord, U. S. Army:

"My visit to the mountains of North Carolina was undertaken to satisfy myself with respect to the numerous rumors which had reached us of the volcanic disturbances in that section of the country. I could spend but two days (19th and 20th March) in the investigation, but was quite diligent in collecting facts and in extending my explorations on horse and on foot so as to cover a distance of eighteen or twenty miles. I was soon convinced that the physical disturbances were real, but many of the rumors were false, and that the truth had been much exaggerated by the fears of the people. The explosive noises accompanying the shocks and the limited area of the disturbances are peculiarities worthy the attention of scientists, and demand a more thorough exploration. The inclosed is a hasty report of my trip, which I drew up to allay, if possible, the fears of the inhabitants of the district.

Stone Mountain, the site of the disturbances, like all the neighboring peaks, is composed chiefly of gneiss and granitic slates, and covered with a dense forest growth. In a direct line, it is about fourteen miles from Black Mountain, or "Mount Mitchell," the highest point in the United States east of the Rocky Mountains. It lies between Broad and Catawba Rivers, both of which point to Black Mountain, while on the northwest side of the Blue Ridge, the Swannanoah and Green Rivers, tributaries of the French Broad, have their sources near the Black Mountain. So many large rivers, on both sides of the Blue Ridge, heading up in this section, would indicate Black Mountain as the center of the volcanic force which lifted up these mountain-ridges. I expect to visit these mountains again in July, when I shall have more time to investigate this matter.*"

Extracts from report above referred to, dated Spartanburgh, S. C., March 28, 1874.

On Wednesday, the 18th of March, in company with Rev. R. C. Oliver, editor of The Orphans' Friend, Mr. McKenn Johnstone, civil engineer, and the senior class of Wofford College, I started for Hickory Nut Gap, for the purpose of making such personal observations as my limited time would permit, and of collecting and sifting all the testimony that I could gather from the inhabitants of the affected region. At Rutherfordton, we were joined by Capt. William Twitty, an educated gentleman, who gave us much assistance in our explorations.

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* Professor Du Pré has been requested to communicate a report of this projected trip. Further data remain to be gleaned, as the phenomena appear to have continued, at least, up to April.

To understand the bearing of the facts and testimony upon the question whether these disturbances threaten a volcanic eruption, as a preliminary, I shall describe, as clearly as I can, the situation of this mountain. Five miles east of Hickory Nut Gap, lies this high mountain-ridge, bearing upon its back several peaks, the highest of which are called Bald, Stone, and Round Mountains, and extending from southwest to northeast, a distance of ten miles, in the order in which they are named. They constitute one mountain-ridge from 3,000 to 3,500 feet high, flanking the Blue Ridge, nearly parallel with it, bounded on the east by Crooked Creek, and on the west by Broad River, which, with its narrow valley, separates them from the high ridge of mountains that border the eastern side of Hickory Nut Gap.

Directing our course along the eastern slope, we came first to the house of Rev. Mr. Logan, a Baptist minister, from whom we learned that the noises and shocks were first heard and felt in Stone Mountain, on Tuesday, the 10th of February; that they were repeated on the following Sunday, with increased severity, so much so that the people sent for him, a distance of ten miles, to hold religious meetings with them; that he and his wife heard the explosions, and felt the shocks repeatedly day and night, once causing the lightning-rods attached to his chimneys to rattle considerably, the sky being clear, and no wind blowing; that the sounds came from the direction of Stone and Bald Mountains, were at first explosive, followed by a slight rumbling lasting for a few seconds, similar to a blast from a stone-quarry; that the shocks were almost instantaneous with the explosions, very rapid, making the ground tremble for a few seconds. In response to an inquiry, whether any one was blasting rock about the mountains, he replied that none could be found, and there was but one quarry, thirty-three miles distant in an opposite direction, and that had not been worked for several months past.

After going two or three miles further, we turned to the left, and were ascending Fork Knob, over which the road leads to the top of Stone Mountain, when a loud explosion in the direction of Stone Mountain startled us all. It was instantly followed by a low reverberatory sound, as if descending the slope of the mountain. We felt no shocks, which was due, no doubt, to the steep and stony road over which our buggies were passing at the time. This was on the 19th, at 5. p. m. Two of our company who had preceded us a mile, and were about a half mile from the top of Stone Mountain, heard the report, and also felt the ground tremble under them. The sound resembled the suppressed but sudden report of a quarry-blast, and seemed to come through the mountain. We arrived about sunset at Mr. Elliott's, whose house is situated in a depression between Round and Stone Peaks, about a half mile from the top of the latter. From Elliott's house, Round Mountain bears north 37° west, Stone Mountain south 73° west, and are about a half or three-quarters of a mile distant from each other. This house being about the center of the greatest agitation, and whence most of the exaggerated rumors had their origin, we determined to remain all night, and I kept watch until about two o'clock. * * * * * * * The next morning I gathered from Mr. and Mrs. Elliott, in answer to many inquiries, the following statement: "The first noise and shakes (as the shocks are very expressively denominated by the mountain people) were heard and felt on Tuesday, 10th February—some of them were felt as far as White House, on Cove Creek, eight miles distant. Sunday morning these sounds and shakes were repeated with increased severity, one a little after sunrise, another at 10, and another at 2 o'clock in the night; noises continued, some with shakes, and some without, until Thursday following, with intervals of about an hour or two. The house—a stout log building—shook so violently that the children became very much alarmed, all thinking it would fall. A ladder resting upon a support in the yard rattled frequently, and the ground seemed to tremble under their feet. The noise began like explosions of a quarry-blast, in the northwest, and west off to the southeast, with a rumbling sound under ground. The weather was quite variable, sometimes cloudy and rainy, at other times clear and cool. The people about the mountain were very much alarmed; had preaching and prayer-meetings daily for a week or more, and forty-five new members were added to the Baptist church."

About 9 o'clock in the morning of the 20th we began the exploration of Stone Mountain. From the base to the summit it is covered with a dark rich soil, about a foot deep, partly cleared and cultivated, but mostly clothed with a growth of heavy timber, consisting of chestnut and oak. The granite slates, about the thickness of flag-stones, scattered over the surface, indicate that the formation does not differ from most of the surrounding peaks. Near its highest point several large blocks of coarse granite protrude through the soil to the height of about 10 feet above the surface. Owing to the depth of the soil and the slight exposure of the rocky formations, I could not ascertain the direction or angle of the dip. No specimens were found which resembled what are usually called volcanic rocks. The mountain appeared as calm and peaceful as if it had never been disturbed since the morning of its upheaval. It presented no cavernous depths or rugged prominences to excite the fears of the dwellers upon its slopes. A dozen or more of the mountaineers had followed us everywhere in the exploration, and, although much alarmed at the frequent agitations of this hitherto stable mountain, yet they unanimously contradicted the many rumors of gaping rocks, smoking peaks, sinking [illegible] melting snows, &c., with which our newspapers have been teeming for many weeks past. We remained on the summit for some time, hoping for an opportunity to determine whether the explosions came from the east or west side of the mountain, or from the ground under our feet. As nothing occurred to settle this question, we descended the western slope to Mrs. Murphy's saw-mill, about eight miles from the head of Broad River. A portion of our party, who had passed two miles around the base of the mountain, heard three loud explosions, and felt two distinct shocks proceeding directly from the peak which we had left but one hour before. This I did not hear or feel, as I was engaged at the time in taking notes of the testimony of Mr. T. J. Dalton, amid the rumbling of machinery and the roar of the mill-dam.

It is unnecessary to give, in detail, all the testimony which we collected from the people while passing along the eastern and western side of this mountain, including a distance of eighteen miles. They all concurred in the following summary: That there were certain days marked by loud reports and severe shakes; that from fifty to seventy-five shocks have been felt since the 10th of February; that the noise begins with an explosion like a quarry-blast, followed by a rumbling sound, lasting only a few seconds; that the shocks are simultaneous, or almost so, with the reports, and seem to follow the direction of the rumbling sound, with this exception, that those near the top of the mountain assert they appear to be under and all around them; that the reports all came from the Stone and Bald Mountain Ridge, those living on the east side pointing to the west, and those on the west pointing to the east for the direction of sounds; that these reports occur as often during the night as the day, in fair weather as in foul; that the effects are felt five miles on each side of the mountain-ridge, and extend from Broad River on the southwest to Catawba on the north, a distance of twenty-five miles; that houses shake, trees with their dead leaves tremble, glasses and crockery rattle, shavings in their workshops shake and "quaver," as one expressed it.

This testimony was collected from thirty or forty men and women of different degrees of intelligence, and their remarkable concurrence in the above statement places the facts beyond the possibility of doubt.

Several hypotheses have been proposed to explain these facts. One is, that the blasting of rock about the mountains will account for all of them. Upon this point we made particular inquiry. There is certainly no operation going on about Stone Mountain, and as the work upon the tunnels in Swannanoah Gap has ceased for more than twelve months, there is no occasion for blasting anywhere else, as fine stones for building purposes, of every form and size, are scattered over all these regions. Besides, any one acquainted with the law of sound knows that the vibratory motion communicated to the matter in the crust of the earth by a blast (supposing it capable of extending to a great distance) will be felt much sooner than the undulations of the atmosphere, which transmit sounds. A person, therefore, standing a thousand yards from a quarry feels the trembling of the earth some time before he hears the sound of the blast. But in all these convulsions of the mountain the concurrent testimony is that the sounds and shocks are either simultaneous or nearly so. The blasting of rock, therefore, cannot account for this important fact.

Another hypothesis is, that these effects may be the result of electricity escaping from the mountain to the cloud, or descending from the cloud to the mountain. There is nothing in the known operations of electricity to produce effects of this kind. Furthermore, these sounds and shocks occur as often in fair as foul weather; and the sounds are altogether different, as we had an opportunity of comparing them during our first night's stay upon the mountain. Electricity never explodes unless it meets with a bad conductor, and as the mountain affords it an easy transit, the explosion must take place somewhere between the summit and the cloud, or along the line of its pathway. The explosion, therefore, being in the air, must be subject to the same laws of sound as the blast of the quarry, and the same method of reasoning will apply in this case as in the other.

The simultaneousness of the shocks and explosions proves that the sound has not far to travel through the air to reach the observer; and while the *primary* cause of the explosions may be deeply seated in the earth, yet the *immediate* cause of the sounds may be at or near the surface. It is known that the loudness and intensity of sounds depend upon the amplitude of the sound-wave. Suppose, then, that the cause of these explosions be deeply seated in the crust of the earth, the force acting and reacting upon the superincumbent strata will impart its vibrations to them and transmit through them its impulsions to the atmosphere above.* I am inclined, therefore, to the opinion that most of the noises accompanying earthquakes are the results of vibratory movements in the earth's crust, or are the secondary effects of a force acting at great depths beneath. This opinion seems to be sustained by the evidence of the witnesses upon the summit as well as five miles from the base of Stone Mountain, all of whom concur as to the simultaneousness of the shocks and explosions. To this it may be objected that earthquake-shocks are often unaccompanied with noises, or that the former may precede the latter by several minutes. In reply, I will state that the crust of the earth is composed of different strata, some capable of transmitting vibrations that are audible and others that are not, as a string may be made to vibrate and yet produce no audible sound. Now, suppose our observer to be standing upon a section of the earth's crust which is incapable of receiving or imparting sound-vibrations, he may feel the earthquake-shocks and yet hear no noise; or, if sounds should reach him after an interval of time, they may come from a distant section capable of producing them, but which must be transmitted to his ear through the intervening atmosphere.

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* This explanation is undoubtedly correct; the velocity of the sound-wave in the earth is the same as that of the wave of percussion; or, in other words, the two are identical. An ear, therefore, placed at the surface of the ground would at any point hear a sound simultaneously with the shock. J. H.

This discussion leads me to the conclusion that the phenomena connected with the agitation of Stone Mountain must be referred to that general *volcanic* or *earthquake force*, which seems as necessary to the economy of nature as light, heat, or electricity. I am not bold enough to venture a theory sufficiently broad to explain these peculiar phenomena. I cannot penetrate the earth to examine the configuration of its inner surface. There may be broad and high arches under which the earthquake-wave may move without disturbing the crust above; or there may be deep depressions presenting walls, against which the molten tide may beat and break and send up its thundering vibrations to the summit of the loftiest mountain. All this is hypothetical and unsatisfactory. But although we are not sufficiently acquainted with the nature of this force, its modes of action and the laws which govern it, to suggest a theory capable of explaining all the phenomena, yet we may examine the facts with reference to the probability of Stone Mountain becoming an eruptive volcano. While the explosive character of the sounds, simultaneousness of sounds and shocks, and the limited area of agitation seem to indicate some local cause, yet the general rule which regulates the distribution of volcanoes on continents seems to militate against such a conclusion. Volcanoes are arranged along the border regions of continents, as between the Pacific and Rocky Mountains, on islands of the coast, or oceanic islands. They are generally confined to the borders of larger oceans and are seldom found in the interior of continents. There are none in America east of the Andes and Rocky Mountains, and no remains of volcanic action have ever been found along the Appalachian range. These are important facts, indicating no chance results, but pointing to a natural law which regulated their geographical distribution. And when we consider, too, that volcanoes, with but few exceptions, are only a few miles from the sea or lake; that the Blue Ridge, of which Stone Mountain is only an appendage, is two hundred and fifty miles from the Atlantic, and presents no marks of former eruptive action, we cannot believe that in these latter days it will behave itself unseemly and do violence to that natural law which planted it in the garden-spot of the South, and gave to the Carolinas the grandest, loveliest scenery on the Appalachian range.

[The following suggestions may be considered as a possible solution of the phenomena in question: It is a well-established fact in geology that the surface of the earth has undergone and is undergoing changes. The highest mountain-chains have been in past geological periods beneath the surface of the sea, as is evident from the marine shells which are found in their strata. It is also well established that some portions of the earth's surface are at present gradually rising and others slowly falling. Now, if we assume that the region around Stone Mountain is undergoing a very gradual elevation or depression, then it will follow that the rocky strata will be brought into a condition of stretching or tension which will go on until the limit of elastic cohesion is reached, when a rupture or crack will suddenly take place which must be attended with a jar, and, in some cases, with an audible sound. If the rocky strata is of the same material from the surface down into the interior; for example, granite, and the mountain being in the process of depression, the crack will take place deep in the interior. If, on the other hand, the mountain is being elevated, the crack will be at the surface. If, however, the upper strata are more extensible than the deeper seated, the crack may be in the interior in the case of an elevation as well as in that of a depression.

It has of late years been suspected, from the discrepancy in later and older measurements of points on the Andes, that this mountain system is in a state of very slow subsidence.

If the foregoing views are correct there is no indication of a volcanic outburst; and whatever moral effect the disturbances may have on the character of the inhabitants of the region, there is little danger as to any physical changes taking place of sufficient intensity to endanger life.—J. H.]

REPORT ON THE TRANSACTIONS OF THE SOCIETY OF PHYSICS AND NATURAL HISTORY, OF GENEVA, FROM JUNE, 1872, TO JUNE, 1873.

BY PROF. A. DE LA RIVE, PRESIDENT.

[Translated for the Smithsonian Institution.]

GENTLEMEN: Called a second time, through your kindness, to preside over you, again I have the honor to present the annual report of such of your transactions as your president has considered it desirable to register. Happily, this year, that part of the report appropriated to biographical notices is extremely brief. The society, after the great losses it sustained during last year, has not this year been called to mourn a single one of its ordinary regular members. But of its honorary members two have been taken away, Madame Somerville and Arnold Escher de la Linth.

I have little to say of Madame Somerville, who has made for herself a brilliant reputation, during the last fifty years, by her mathematical works, and especially by her translation into English of the Mécanique céleste of Laplace. She was in full sympathy with the different branches of science, and well informed as to their progress. She had for several years resided in Florence, where she died at an advanced age.

Arnold Escher de la Linth was a son of the celebrated Conrad Escher, surnamed de la Linth on account of the great service he rendered to the valley of that name, by directing the river Linth into Lake Wallenstadt, in order to protect the valley from inundations; an admirable work, managed with great talent and perseverance.

Arnold Escher acquired at an early age, under his father's tuition, a love for the natural sciences. Conrad Escher was in fact one of the most eminent naturalists of his time; his observations in regard to the dispersion of erratic bowlders, and their distribution over the Swiss plains, are especially remarkable.

The son, during the frequent excursions made with his father into the mountains of Glaris, formed the conception of a geological map of Switzerland, which he afterward executed and published, in concert with M. Studer, the eminent geologist of Berne, after twenty years of labor and innumerable journeys. He examined the Alps in every detail, and the precision and justice of his judgment, the accuracy of his observations, and the quickness of his comprehension permitted him to accumulate more abundant material for study than unfortunately he could make use of.

The desirable qualities we have mentioned inspired confidence, and he was frequently consulted; his answers were always characterized by a straightforward integrity, and a scientific accuracy quite exceptional, as well as a liberality rarely met with, which rendered him indifferent as to whether or not his ideas were appropriated by others. The perfect honesty and great conscientiousness with which he pursued his researches often prevented him from publishing them. He was always afraid of not having sufficiently investigated the ground gone over, and would go again to places he perhaps had previously visited many times.

He belonged to the geological commission of Switzerland, and was one of its most influential members. This commission assigned to him the preparation of the part of the Federal Atlas which contained the Sentis. He had devoted more than twenty years to the study of this mountain, and as early as in 1848 the cuts furnished to Murchison, which were published in the memoir of the English *savan*, prove that he was master of the subject. When death prevented Escher from making the publication which had been intrusted to him by the commission, the latter found among his papers, with many inestimable scientific treasures, enough documents to prepare a large special map of Sentis, on a scale of fifty thousands, (the ordinary maps of the commission were of one hundred thousands,) with text, both almost entirely from the hand of Escher, a work which reflects much honor on his memory.

I should also add that Escher joined MM. Martins and Desor in an expedition to the desert of Sahara, the results of which, especially those which relate to the meteorological influence of the simoon, or wind of the desert, upon the meteorological condition of the Alpine regions, were given in the account of the expedition published by M. Desor, under the form of letters addressed to M. Liebig and M. Ch. Vogt.

A description of Arnold Escher would be very incomplete were it confined to an account of his scientific life. The integrity and love of truth which distinguished him in his researches, he carried into his private relations, where they were associated with great simplicity of manner, and, we may say, perfect amiability, accompanied by a slight diffidence, which only rendered him the more attractive. It was a real pleasure to see him enter our reunions of the Helvetic Society of Natural History, into which he brought a warm and cheerful kindliness it is impossible to forget. The void made by his death has been deeply felt, and in the month of August last, at the Fribourg meeting, every one deplored his absence, with that of our excellent colleague Pictet de la Rive. It was a great sorrow not to meet again the two friends, lately so full of life, and with nothing about them to indicate premature death.

If the society lost none of its ordinary members during the year that is passed, it added several to its number. MM. Emile Ador, Edmond Sarasin, and William Barbey were elected as ordinary members, on account of interesting communications made by these young *savans* in regard to organic chemistry, geology, and botany. M. Casin, professor of the lyceum of Charlemagne, well known for important researches in physics, of which he in person made an exposition, in part, at a session of the society, was elected an honorary member. The society has chosen as president, for the year commencing to-day, Professor de Candolle, and has re-elected as treasurer, for three years dating from the month of January, M. Philippe Plantamour. Finally, it has acquired two new free associate members, MM. Edouard Des Gouttes and Henri Hentsch.

The second part of volume xxi of our memoirs appeared at the end of 1872; it contained, besides the report of the president, an article upon the *Lepidoptera* of the Museum of Geneva, by M. Guénée, whom the society elected last year as honorary member; the fourth series of a work by M. Duby on new, or not well known, cryptogams; some observations upon a primordial group of plants (*appendiculaires*) of the Strait of Messina, by M. Hermann Fol; and, lastly, an important memoir upon the effects of lightning upon trees and ligneous plants, and the employment of them as conductors or lightning-rods, by M. Daniel Colladon.

Independently of the first part of volume xxiii, which will appear in the course of the year, the society, thanks to the generosity of M. Claparède, sen., and of his daughter, Madame Flournois, has added to its memoirs, as volume xxii, the last work of M. Edouard Claparède, prefaced by a biographical notice of our lamented colleague, by M. Henri de Saussure. This volume, which is already printed, will soon be given to the public.

The society is still occupied with investigations in regard to the lake of Geneva, and has received several reports of the commission from M. Alphonse Favre. After allotting a sum of 500 francs from its funds to commence this work, in order to defray the subsequent expense the society has opened a special subscription, which has brought in 1,800 francs net. The first soundings undertaken by M. Favre, assisted by M. Henri Hentsch, cost 336 francs 75 centimes, which sum was taken from a donation to the commission of 700 francs—400 from the Geneva society and 300 from the Vaudois society. In the following account of the labors of the society will be found some of the scientific results obtained.

I mention, merely to recall the fact, the examination made by the society of the changes proposed by the central committee of the Helvetic Society of Natural Science in the existing constitution and title of the society. It has given an opinion unfavorable to their adoption, especially that which relates to a diminution in the number of days of a session, which the committee proposed to reduce to two. The society has always admitted that the local committee could, when desirable, make this reduction.

SUMMARY OF SCIENTIFIC LABORS.

1. *Physical science.*—The mathematical sciences which, without a strict regard to the laws of classification, I enter under the head of physical science, have been well represented in our sessions.

M. Galopin has given us a method of determining the maxima and the minima of a function. It consists in reducing to 0 the derivative of the function, and then arranging the roots in the order of their powers. In this order they correspond alternately to a maximum and a minimum, so that it is only necessary to determine the derivative of one of them.

M. de la Harpe has exhibited a property of numbers by which it results that the cube of one number is always equal to the difference of the squares of two other numbers.

We commence the enumeration of the works of the society in physical science proper, with meteorology.

M. Plantamour has given a summary of the udometric observations for the meteorological year 1872. From the commencement of our regular observations, that is to say, from the year 1826, there has never been as much rain in one year as in that of 1872. The annual mean at Geneva is 824^{mm}. In 1872 there fell $1{,}086^{mm}$; that is to say, over a third more than the mean.

M. Plantamour has kept the society informed in regard to the geodetic operations carried on in Switzerland. The purpose of the geodetic campaign of 1872 has been to determine the co-ordinates of the Gebris, in the canton of Appenzell, the Gebris being one of the points of the new international triangulation, intended to connect this mountain with the Austrian triangulation. An error in the closing of a large polygon passing through the Simplon and the Gothard necessitated a new set of operations, for there was an error in taking the level of about 1^m, which was inadmissible. The cause of this error has not yet been discovered. The errors which are found out by the closing of a polygon have also been the subject of a communication from General Dufour, who has mentioned the deviation of the plumb-line, on account of the neighborhood of the mountains, as a possible cause of the want of accordance between the two levelings.

Our society, in concert with the Vaudois Society of Natural Sciences, has decided, as you know, to undertake an examination of the bottom of the lake. In view of this work, MM. A. Favre and H. Hentsch have made some preparatory soundings, which have been the subject of a communication to the society. The process of determining a profile by soundings, which consists in causing an experienced rower to give the same number of strokes of the oar between two consecutive soundings, is not sufficiently precise; at least it did not prove to be so under the conditions in which the observations were made. Under other circumstances it might be useful. If, on the contrary, the profile is obtained by means of a rope supported by corks, results may be corrected by a second operation. The depth of the little lake is in some parts much greater than is indicated in the map of the canton.

I am constrained to mention in this connection the communication by M. Chaix of a hydrographic map, published by the federal bureau, to which M. Chaix has added his experiments upon the proportion of solid matter contained in the water of the Arve.

On the 27th of November of last year occurred that remarkable rain of meteors, which seemed to confirm the hypothesis that shooting stars are produced by the disintegration of comets. M. Plantamour gave to the society the data for the solution of the question, to which the attention of the society was again directed by M. E. Gautier, in the course of a notice of the presumed discovery of the comet of Biela by an astronomer of Madras.

I complete the notice of astronomical researches by mentioning the remarkable instance communicated by M. Thury of astronomical visibility. He observed, by means of his small refractor, with great clearness, on the night of the 15th to 16th of June, the star Antarès and the small blue star near it.

Want of space permits me merely to recall to your memory, without analyzing it, the communication of M. Soret in regard to his comparative researches between thermal solar radiation and that of a body heated in the oxyhydric flame. These researches, which modify the assertions of P. Secchi in regard to the temperature of the sun, have been published. I would say here, that it is our custom, in our annual account of the proceedings of the society, to confine ourselves almost exclusively to communications which have not been laid before the public. I give, once for all, this explanation, to account for the more or less brief notice of some of the subjects which have been discussed at our sessions.

M. Wartmann discussed the theory of the perception of color, which admits three systems of nerves, corresponding to the three fundamental colors, and opposed to this theory certain observed facts; in particular, the fact that certain Daltonians do not perceive color, but only a contrast of light and shade of different intensities.

Information in regard to the aurora borealis has, from time to time, been sent to me by observers of this phenomenon and by savans interested in the subject. I have communicated to the society the principal inferences drawn from a work of M. Boué, upon the concordance of austral and boreal auroras which he sent me in a letter, and also those from the researches of M. Lovering, who has united in a catalogue more than 12,000 observations of auroras.

M. Marignac has given us the result of his experiments upon the identity of the heat of fusion and the heat of solution. The temperature of solution of a body whose point of fusion is very low was observed during the cooling, and particularly as it passed the point of fusion. There was no sudden change, nothing anomalous, as it passed this point; and M. Marignac therefore concluded that the heat of fusion is identical with that of solution. For this experiment a solution of spermaceti in alcohol was used; the point of fusion was at 48° C. The substances which meet the conditions required by these researches are few in number.

M. E. Ador has presented to the society a summary of his researches in regard to the radical of phtalic acid.

I close the account of our labors in physical science by mentioning the oral summary given by M. Casin of some of his researches, already printed, which he has presented to the society.

I also recall that Professor Gautier in numerous reports, several of which have been published in the archives, has informed us of various astronomical investigations, and in particular of those of M. Huggins of stellar spectra in regard to the direction of the movement of stars in relation to the earth.

2. *The natural sciences.*—Geology and paleontology have so much in common, that it seems to me quite natural to mention in connection what relates to these two sciences.

I would remind you that M. A. Favre presented an article upon phosphates, and their beds, and that M. E. Favre made the society acquainted with the recent works upon the structure of ammonites.

The boring of the Gothard cannot fail to interest geologists. Specimens of the different rocks encountered will be preserved in their order of succession. M. A. Favre, in making a communication to the society upon this subject, suggested the request for a set of these specimens for the Museum of Geneva.

M. Ed. Sarasin presented an article, prepared with the assistance of M. Fuchs, upon the sources of the petroleum of Câmpina, in Wallachia. This article assigns to petroleum an eruptive origin, and assimilates it to the hydrocarbons disengaged during volcanic phenomena. This hypothesis led the authors to expect that they would find in beds of petroleum a distribution analogous to that of metalliferous strata; their anticipations were confirmed by the discovery of an *orientation*, following two parallel lines, in the petroleum-emanations of the plateau of Câmpina.

M. de Saussure, on his return from a visit to Naples, gave us a description of the crater of Vesuvius, then in eruption, (see the Journal of Geneva,) and also presented the society with several other communications, upon various subjects, which have already been published.

M. Dor exhibited to us three skulls of the lacustrian period, recently discovered. Two of these skulls belong to the stone age, and are therefore very valuable, on account of the rarity of such specimens, a rarity probably due to the custom of burning bodies. They are skulls of the ancient Helvetians, a Celtic race. The large size of one of them shows that the stature of the man of the stone age was greater than has been supposed. The third is the skull of a child of the bronze age.

Under the head of "animal physiology" should be recorded the researches of M. Prevost upon the section of the cord of the tympanum. Contrary to the opinion first announced by M. Vulpian, and afterward modified by this scientist's own observations, M. Prevost found that the cord of the tympanum is not entirely lost in the lower maxillary gland, but sends threads to the tongue. Employing the Waller method, he divided the tympanum-cord of dogs, cats, &c., and a few days after found wasted nervous tubes in the terminal branches of the lingual.

M. Prevost has given us the results of some experiments upon the nerves of taste. These are opposed to the hypothesis that the fibers, of the lingual nerve which transmits the gustatory impressions, pass through the spheno-palatine ganglion. In fact, the amputation of two spheno-palatine ganglions, accompanied by the section of the two glosso-pharyngeal nerves, does not alter the transmission of the gustatory sensations in the parts moved by the lingual nerve.

Under the head of physiology should also be mentioned a communication concerning the investigations of the congress of medical men at Lyons, in regard to the supposed cause of the fevers which justly give to the climate of the Dombes a character for insalubrity. In this communication the intermittent fever of these regions is attributed to the spores of a conferva, very abundant in the marshes of that neighborhood, which rise in the air, with the water evaporated.

M. Lombard, in regard to a subject upon which he had before addressed the society, presented the fact that pulmonary consumption or phthisis decreases with altitude, and mentioned Davos station, at an elevation of 1,556 meters, as having been found particularly favorable to persons affected with this disease.

In natural history proper, M. V. Fatio has given an account of his researches in regard to the development of the black salamander, which differs greatly from that of the spotted variety. The black salamander produces only two living progeny, although at the same time the ovary contains a large number of eggs. Four of these eggs are developed at the expense of the others, which are decomposed and serve them as nourishment; after a time the development of two of the four embryos is arrested, and they in turn serve as nutrition for the last two, which alone survive, and are born after undergoing various metamorphoses.

M. Lombard exhibited to the society a blind fish from the Mammoth Cave of Kentucky, sent to the Museum of Geneva by M. V. Lombard.

Vegetable physiology has been represented, first, by a communication from M. Rissler, upon the nutrition of plants. M. Rissler reminded the society that he had before presented some researches upon the double part played by the humus, which assists the dissolution of the mineral substances useful to the plant, and also furnishes a portion of the carbon it contains. His views were opposed to a subsequent memoir upon the same subject, to which he drew attention, by M. Grandeau, in which M. Rissler's researches are not mentioned, and according to which the part played by the humus consists only in dissolving the nutritive substances.

M. de Candolle, in noticing the appearance, recently observed, of Algerine plants in France, expressed his doubts as to their definite establishment, and gave some examples of exceptional and temporary development of plants.

While exhibiting to the society a flower of the orchid order, the *Angræcum sesquipedale*, a plant which is a native of Madagascar and only very recently introduced into Europe, M. E. Boissier gave us the views of Darwin in regard to the mode of fecundation of this flower. It is remarkable for a spur of extraordinary length, the elongation of which Darwin considers must be the consequence of the length of the proboscis of a certain butterfly which is still unknown, and which would be the only insect which could determine the fecundation of this orchid. In fact, in all the flowers provided with short spurs, as this butterfly touches the nectar with the end of its proboscis, and does not introduce the latter entirely, it does not carry off pollen with its head. Such flowers, in consequence, do not participate in the fecundation of the others, and tend to disappear. M. Boissier made some objections to this theory, which he considers insufficiently founded upon observation and even logical deduction.

M. Müller claimed to have proved in a striking manner the intimate mingling of the two distinct forms of the ordinary cowslip or primrose, and gave this fact as a remarkable example of dimorphism. He recalled to mind that if fecundation takes place under the most favorable conditions, it must be between flowers of opposite form.

A communication was made to us by M. Lichtenstein, of Montpellier, upon the ravages caused in vineyards by the *Phylloxera vastatrix*. In the same family of plants certain species seem to be spared by this disease. Thus, although the European vine transported to America may be affected by it, it does not attack the vine indigenous to America. M. Lichtenstein has not observed in Switzerland the injurious species of *Phylloxera*.

Lichens, and the theory of M. Schwandener, according to which they have been assimilated to a combination of mushrooms and sea-weeds, have been the subject of a communication from M. Müller. It is true that the anatomic structure of lichens exhibits the superposition of green cells called gonidés, and this is analogous to that of sea-weeds, also a felty tissue containing no chlorophyl, in which it resembles the organization of mushrooms; but still we never find among the lichens the effects produced by the parasitism of the mushrooms, and there exist among them forms of fruit and spores never found among the mushrooms. M. Müller does not accept this theory, and sees in lichens a dimorphism of which the two terms are: 1. A complete state, known under the name lichen. 2. An incomplete state, never producing fruit, and which corresponds to the lichen which grows in an isolated condition.

M. Duby informed the society that an anomalous moss had been sent to him from New Caledonia. He described two characteristics found in no other known moss, which establishes a new genus. The name Mr.

Duby has given to this genus is *Sunodontea*, and the species has been called *Spathoidea*.

M. de Candolle has stated to the society that a plant, the *Linnea borealis*, whose existence in our vicinity has been unknown since De Saussure found it growing upon the Voirons, had been discovered by M. P. Privat, upon the pass of Oche.

M. W. Barbey presented to the society an article upon plants of the genus *Epilobium*. In this genus there are some especial difficulties in the determination of species, concerning which there is great uncertainty, notwithstanding numerous investigations. The seed ought to furnish the best characteristics for determination, but the *Epilobia* multiply readily by suckers, which favors the permanence of the hybrid specimens which abound in this genus. These plants are found in great abundance in New Zealand.

M. Humbert has presented several very interesting communications upon some publications relative to natural history, particularly upon the work of Hæckel on calcareous sponges.

I ought also to mention several reviews, presented by different members, of published works; among others, that of M. Ernest Favre, of the work of M. Barrande upon the silurian formation of Bohemia, and those of M. Micheli, of the new edition of the treatise on botany of M. Sachs, and of a work of M. Krauss, professor of botany at Erlangen, upon the coloring matter of chlorophyl.

If I do not dwell upon communications of this kind, it is because, in the reports of the president, as I have said before, it is customary to confine attention principally to original papers; but I cannot terminate this report without special notice of the communication, so full of interest, made by M. Alphonse de Candolle to the society, in its session of June, 1873, the last at which I had the honor to preside. In announcing the publication of the seventeenth and last volume of the *Prodromus systematis naturalis regni vegetabilis*, he gave an historical summary of this great and important work. I willingly extend this detailed account of what I consider one of the most glorious memorials of the science of Geneva.

The idea of making a complete revision of the vegetable kingdom was conceived by Augustin Pyramus de Candolle, during the last years of his residence in Montpellier, about 1813 or 1814.

The end he proposed to himself then, especially, was to improve and diffuse the knowledge of the natural system he was the first to make use of, in an important flora, (Flore française, 1805,) and the principles of which he unfolded in his elementary treatise, (1813.) He began with some monographs of families, very carefully elaborated, which he published in two volumes called *Regni vegetabilis systema naturale*, (1818 and 1821.) He soon saw that to treat every family in this way would be beyond the powers of one man, and would require a great deal too much time, even supposing, as was then believed, that the number of species did not exceed 25,000 or 30,000. De Candolle modified his plan, and took up the series of families under a very much abridged form in his work which he called the Prodromus. The title indicates that he at some future time hoped to take up again the *Systema*, but the enormous increase in the number of species discovered, after the peace of 1815, soon convinced him that this was impossible, and as the articles in the Prodromus were considered too brief, he lengthened the descriptions, after the third volume, and continued to do so until the middle of the seventh volume. There he came to the end of the great family of compound flowers, the elaboration of which was his last and greatest effort.

He was attacked by a serious illness just as he attained his sixtieth year, and was obliged to accept of assistance in the work of continuing the Prodromus, which he had never before done, except with articles of very little consequence. MM. Bentham, Dunal, Decaisne, Grisebach, Choisy, Duby, Boissier, Moquin, Meissner, and Alphonse de Candolle contributed their aid, and gradually furnished extended articles. De Candolle expired on the 9th of September, 1841, and his son continued to direct the Prodromus, preparing himself certain articles. With the aid of other assistants, at the end of thirty-two years he had added ten volumes to the seven that his father had published. The seventeenth volume completed the principal class of the vegetable kingdom, the Dicotyledons, with the exception of one family (*Artocarpeis*) which the author could not prepare in time, notwithstanding the delay accorded him. The whole forms a series of unparalleled monographs, including 214 families, 5,134 genera, and 58,975 species.

The Prodromus has been, we may say, the great authority of descriptive botany for half a century. Its order for families has generally been adopted, its form of compilation imitated, and what it proposes or sanctions admitted. It has been of great service in doing away with a number of genera and species for which there was no foundation. As the work was published when most of the new plants were discovered, it contributed greatly to making them known. It includes 657 new genera and 11,790 new species; that is to say, more than Linnæus knew of for the whole vegetable kingdom. M. de Candolle shows, by comparing the volumes three by three from the commencement of the work, that the proportion of new genera in relation to the old constantly diminishes, while the proportion of new species remains the same; that is always about 25 per cent. We may, therefore, conclude that by the end of the present century we shall have discovered very nearly all the genera which exist, while with species this is still far from being the case.

One of the causes of the influence of the Prodromus has been its entire impartiality with respect to the botanists of all countries. The authors have been chosen without reference to nationality. They are thirty-three in number, including MM. Candolle, and of these thirty-three contributors twelve are Swiss, nine French, seven German, three

English, one Italian, one Swedish, one from Holland, and one a Belgian.

Augustin Pyramus de Candolle has written almost a third of the work, 4,303 pages; Alph. de Candolle, 1,387 pages; J. Müller, of Argovie, 1,144; Bentham, 1,133; Meissner, 835; Dunal, 732; the twenty-nine other assistants, articles less extended. De Candolle, his son, and his grandson (Casimir) have compiled 5,947 pages out of the whole 13,194. The contributors residing at Geneva have furnished six-tenths.

The mere correction of proof in such an especial work has been a great labor for the two directors, who have done it all themselves. They have also greatly assisted their colaborers, by taking notes for sixty years, without interruption, of all new descriptions and plates which have appeared in botanical books and journals. These notes, classed by families, form the most complete repertory of descriptive botanical literature ever compiled.

Several motives induced M. de Candolle not to extend the Prodromus beyond the Dicotyledons. The principal one was the great increase in the difficulty of the work, on account of the continually-increasing number of specimens to be examined and of species and characteristics to be determined by the aid of the magnifying-glass. When A. P. de Candolle commenced, an active botanist could describe, according to the custom of the time, 1,500 or 1,800 species a year. Now, with the work prepared as in the last volumes of the Prodromus, and in accordance with the existing state of science, an industrious botanist could describe not more than 300 or 400 species a year. The difficulty of obtaining the manuscripts at the time promised by the authors was another great obstacle. To this cause must be attributed the delay in the publication of the Prodromus, the volumes having appeared more and more slowly in proportion as the number of writers was increased.

The execution of this magnificent work has required fifty years, indeed sixty, if we go back to its origin. It has employed three generations of the same family, which is an unusual circumstance in the history of science, and will forever associate the name of Candolle with the most remarkable scientific achievements of Geneva.

WARMING AND VENTILATION.

By Arthur Morin,
Director of the Conservatory of Arts and Trades, Paris.

[Translated for the Smithsonian Institution by Clarence B. Young.]

[*Continued from the Smithsonian Report for* 1873, *p.* 318.]

APPLICATIONS.

55. *Ventilating by means of common fire-places.*—Fire-places, though not economical forms of heating-apparatus, produce a very pleasant temperature, and also serve as efficient means of changing the air of occupied apartments.

Natural draught produced simply by the difference between the temperature of the air within the chimney and that without, in many cases, carries off as much as 14,000 cubic feet of air an hour, even when no fire is burning in the fire-place.

With a coal or wood fire of moderate intensity, the amount of air carried off may be as much as 42,000 cubic feet an hour, or 2,200 cubic feet to each pound of wood burned, and 3,200 cubic feet to each pound of coal burned.

But, with this advantage, common fire-places have the serious defect of drawing in, through the joints of doors and windows, currents of cold air, which run to the fire and chill the backs of those sitting there, an effect which is particularly unpleasant when the face is very much warmed by the fire.

The various forms of apparatus in use, which are designed to warm the apartment, and, at the same time, draw in external air to increase the draft and promote combustion, usually have too small flues, and heat the air to 176°, 212°, or more, which, issuing horizontally at about the height of the occupants of the room, becomes at times unendurable. These forms of apparatus have besides the defect of obstructing the lower portion of the smoke-flue, and of reducing the volume of air carried off. Fire-places made on Douglas Galton's system, with the dimensions given in § 13, do not have these objections, and are unexceptionable means of warming and ventilating during the winter.

56. *Use of chimneys for summer-ventilation by means of gas-jets.*—Chimneys may easily be made to serve as ventilators during the summer, or on special occasions, by placing in them an iron or copper pipe furnished with several gas-burners. In the chimney of an ordinary apartment,

having an earthen-ware flue 11 inches square and 66 feet high, the amount of air drawn up the chimney to each foot of gas burned will be greater the less gas is burned and the less the temperature in the flue, following pretty nearly the following decreasing series:

Amount of gas consumed an hour.	Amount of air drawn up the chimney every hour to each cubic foot of gas burned.
Cubic feet.	*Cubic feet.*
7	1,900
14	1,400
28	700
35	600
42	500
49	450

These approximate figures may serve to determine the number of 3½ feet burners that will be required to produce any desired rate of change of air in an apartment.

When the chimney is much lower than that just mentioned, it will be necessary to correct the calculated volume of air in the proportion of the square roots of the heights of the flues.

The pipe which conveys the gas to the flue may be easily taken away when not in use, and closed by a blind socket.

This mode of ventilation may be employed to advantage in drawing-rooms on reception-days, provided that registers be placed at convenient points for the introduction of moderately warm fresh air.

During the summer, the system of ventilating by means of gas-jets will also allow the room to be maintained at a lower temperature than that of the external air, by drawing in the air from clean cellars to replace that carried off.

Example.—The directors' room at the Conservatory of Arts and Trades is ventilated in this way during the summer; and, although the air from the basement is admitted through but a single opening, entirely too small for the purpose, and the doors of the room are constantly being opened, yet the temperature is always 4° lower than the room of the subdirector, which has a precisely similar exposure, but is unventilated, and it is 7° lower than the temperature of the external air in the shade.

57. *Auxiliary ventilating-flues.*—For unusually large gatherings, in addition to the chimneys, additional flues may be cut in the thickness of the front or party walls, in which gas-jets may be used to produce a strong draught. This method has been tried with success in a house in the Champs Élysées, Paris.

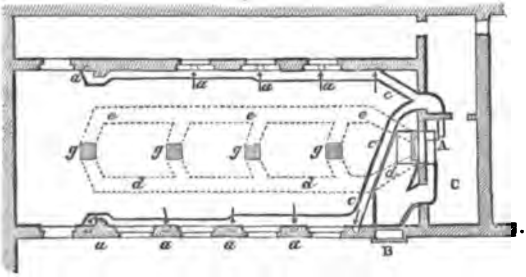
INFANT-ASYLUMS.

58. In these charitable institutions, in addition to securing space and cleanliness, provision should also be made for obtaining an abundant

and regular supply of fresh air, without depending upon the irregular opening of windows.

In this respect, all establishments of this kind, even the model one at the International Exhibition, fall far short. They are warmed by cast-iron stoves, the imperfections of which were shown in §16.

Fig. 14.



As an example of what appears proper to be done in such cases, I will describe the plan carried out in the new asylum in the parish of Saint Ambrose in Paris, the construction of which was intrusted to M. Picq, the architect, (Fig. 14.)

This asylum is intended to receive fifty babies. There will also often be twenty-five mothers there at a time, while the attendants and patronesses present will usually add ten persons more.

With these data, the maximum volume of air to be carried off and replaced by fresh may reach the following figures, (§ 40:)

	Cubic feet.
For 50 babies, (530 cubic feet each per hour)	26,500
25 visiting mothers, (1,060 cubic feet each per hour)	26,500
10 attendants, (1,060 cubic feet each per hour)	10,600
Total amount of air to be changed every hour	63,600

or 18 cubic feet in a second.

This amount greatly exceeds the actual requirement, because the regulations of the asylum forbid the presence of the mothers in the main hall. They are received and nurse their children in a special apartment.

The main room is 61 feet long, 24 feet wide, and 15 feet high, having, therefore, a content of about 22,000 cubic feet. With the amount of air mentioned above, the complete change would take place in $\frac{63600}{22000} = 2.8$ times an hour, which is quite sufficient to keep the room in a healthful condition.

The room is warmed by a hot-air heater, with vertical cast-iron tubes, having altogether about one hundred square feet of heating-surface, communicating with a cold-air duct, which will be described hereafter.

It was intended that this heater should have two chambers: the exterior one, for drying damp linen, carrying the vapor to the chimney; the interior one, opening into the room, for warming dry linen. On account of the expense, these chambers were not made.

There might easily have been placed around the fire-chamber in this heater hot-water pipes connected with a receiver, in order to furnish a supply of water for domestic use.

In summer, the receiver, which, indeed, might have been placed in the chimney-flue, could have been heated by a special fire. This useful appendage was given up for the same reason as the other.

The foul air is carried off through ten flues, *a*, *a*, *a*, (Fig. 14,) made in the thickness of the walls. The required velocity of the current being 2.3 feet a second, (§ 50,) the clear sectional area of each flue has been fixed at $\frac{18 \text{ feet}}{10 \times 2.3} = .78$ square feet.

The size of the openings might then be 1 foot by 9 inches; but, their area being reduced by a register which cuts off about one-third, they have been made 1 foot square.

These flues open into collecting-flues arranged under the floor on each long side of the building; each of these collectors being able to carry off at a maximum 9 cubic feet a second, with a mean velocity of 3 feet a second, (§ 50.) They have at their mouths a sectional area of 2.7 square feet, being about 19 inches square; but, at the first part, up to where the third down-flue enters, their areas have been reduced each to 1.6 square feet, they being 1 foot by 20 inches.

The transverse collectors, *c*, *c*, in which the air should have a velocity of 4 feet a second, (§ 50,) have each a sectional area of only 2 square feet in their transverse portion, being 1 foot four inches by 1 foot 7 inches, and they are but 2 feet 7 inches by 1 foot 7 inches where they enter the chimney, while there they should carry off 18 cubic feet a second.

The chimney, which should carry off 18 cubic feet a second at the velocity of 7 feet a second, (§ 50,) should have the area $\frac{18}{7} = 2.57$ square feet, or be 1 foot 7 inches by 1 foot 7 inches. It really has a sectional area of 5 square feet, which is larger than necessary. It contains the smoke-flue, and it has, near the bottom, a little grate 10 inches by 10 inches, forming a heater, in which a little coal-fire may be made in mild weather in order to keep up the circulation of air.

The introduction of fresh air is made in accordance with the rules given in §§ 51, 52.

The fresh-air supply for the heater A is obtained by means of a pipe, B, carried from the garden and passing under the floor. At its outer end, this pipe is connected with a sort of chimney connected with a grating to prevent the introduction of foreign bodies.

The air to maintain the draught of the fire is taken from the little room C.

The warm air supplied by the heater passes to the upper room by pipes, *d d d*, *e e e*, placed under the floor of the attic-room in the line of the building. The construction of the roof did not permit of using only a single pipe, which would have been sufficient. The cold air to be mixed with the warm air is taken in the upper room, where it is deflected toward the pipes by means of slats, so as to be delivered above the warm-air pipe *d d d*.

A shelf fastened to each side-wall at half the height of the longitudinal pipe *e e e* secures the separate admission of hot air below and cold air above. It is sufficient that these shelves be 10 or 12 feet long, but they should be made of earthen ware, in order that they may not be too much heated by the action of the air from the heater, which might prevent the entrance of the cold air.

The two pipes for warm and fresh air are 12 inches by 20 inches. Four openings, *g*, *g*, *g*, *g*, placed in the ceiling in the center line of the room, admit the mixture of warm and fresh air with a velocity of about 20 inches a second, (§§ 51, 52,) and in order to allow for the obstruction of the grating they are made 28 inches by 35 inches. Registers are placed at the lower part of the chimney to regulate the amount carried off, and they are also placed in the warm-air and fresh-air pipes so as to obtain the proper mixture.

Such are the simple and inexpensive arrangements which serve to maintain in this asylum a degree of healthfulness superior to that of other establishments of the kind.

59. *Results of experiment.*—The plan just described was carried out, with a few modifications in details rendered necessary by local conditions and by work previously done. The asylum was opened January 27, 1868, and experiments made there in the first part of February, which gave the following results:

Results of experiments made in Saint Ambrose Infant-Asylum.—The inside work of this asylum was not finished till the latter part of January, and the hall was opened on Monday the 27th to the first children that were presented. After three or four days of heating to bring the interior to the proper temperature, the experiments were begun on the 31st January.

In the first visit to the hall, it was noticed that the foul air was carried off very well by all the openings, although the velocity appeared considerably greater at those nearest the chimney, as is natural. It would be easy to render the amounts carried off through the openings more uniform, if deemed necessary, by placing a register at each opening and regulating it once for all.

The admission of fresh air is provided for by means of openings in the ceiling, and its velocity does not exceed 18 or 20 inches a second. It can be rendered entirely uniform by partially closing the openings farthest from the heater, but this is not necessary.

The amount of air admitted into the heater to be warmed may vary greatly according to the intensity of the fire, but, with the very moderate consumption of 57 pounds a day, it was found to be, on the 6th of February, 62,000 cubic feet; and on the 7th of February, 59,000 cubic feet, raised from the external temperature 42°, the usual mean temperature of the winter, to 88°, at which it was admitted into the room. The heater, on account of the large dimensions of its chambers, was more than sufficient alone to supply the room in winter with fresh air heated to a comfortable degree. The additional fresh-air ducts would then be often found unnecessary, and might be closed.

The amount of air brought into the room through the openings in the ceiling was found the same day, February 7, to be equal to 60,000 cubic feet an hour, confirming the previous opinion.

The amount of foul air carried off by the ventilating-chimney was as much as 65,000 cubic feet the same day and under the same circumstances. The mean temperature in the chimney was—

February 6	84°
That of the external air being	44°
Difference	40°

Thus, with this mean winter-temperature, that of 61° was maintained in the room, and, with an excess of 40° in the chimney over that of the air, almost 63,000 cubic feet of foul air was carried off, as has been stated.

The consumption of fuel an hour was—

	Pounds.
For heating	7
For the ventilating-chimney	3
	10

The babies being left in the morning and taken away by their mothers in the evening, it will be sufficient, in ordinary weather, if the fires be kept up at most eight hours a day. The daily consumption will then be on a mean $10\times8=80$ pounds a day.

The fuel used is composed of 75 per cent. of coke and 25 per cent. of coal, and it will be estimating it above its value to charge it at $10 a ton. The expense of fuel during the winter would then be at most $\frac{80\times10}{2240}=36$ cents a day, or $36 for 100 days, to obtain a change of air at the rate of 63,000 cubic feet an hour.

During the season when artificial heat is not required, the ventilating-fire alone should be used, and will usually burn not more than about 3⅓ pounds of coal an hour, or 27 lbs. a day, for the period when the opening of windows will not be sufficient, or during 200 days, $\frac{200\times27\times10}{2240}=\$24$. The total annual expense would then be at most $60 for an asylum which, though intended for but 50 children, might easily receive 100 in the large well-ventilated apartment, which has a content of 23,000 cubic feet, giving, in that case, 230 cubic feet for each child; while in the primary schools of Paris there is allowed, on an average, but about 155 cubic feet to each child of from 6 to 12 years of age.

Under these conditions, the ventilation of 63,000 cubic feet for 100 beds, or 230 feet a bed, an hour would be almost double what is necessary, and could easily be reduced to 42,000 cubic feet an hour. But even supposing that it be kept as it is, the mean expense for each child would be at most 60 cents a year.

It should be added that, without urging the ventilating-fire, it is easy, with the proportions adopted, to increase the amount of air removed to more than 88,000 cubic feet an hour.

In conclusion, we see from these experiments that the dimensions adopted in this first application to infant-asylums are much larger than necessary, and that the results intended have been more than realized. It may then be considered certain that in making similar arrangements, even with smaller dimensions, all requirements for good and complete ventilation will be satisfied at an expense much less than that incurred in the asylum which the parish of Saint Ambrose owes to its venerable curate, M. Langenieux.

60. *Proportions for an asylum of fifty cradles.*—According to the results of the experiments which have just been mentioned, and the conditions of service imposed by the regulations, the arrangements adopted by the Saint Ambrose Asylum greatly exceeding the necessities of the case, the following data may be assumed for a similar asylum:

Amount of air to be carried off and replaced for 50 children, at 530 cubic feet each per hour	26, 500 cubic feet.
For attendants and visitors	8, 800 cubic feet.
	35, 300 cubic feet.
Floor room, 16¼ feet to each cradle	812 square feet.
Interior height	13 feet.
Total cubical contents	10, 600 cubic feet.

Equivalent to 212 cubic feet to each cradle.

The air of the room should be changed $\frac{35300}{10600}=3\frac{1}{3}$ times an hour.

The volume of air to be carried off and replaced in a second would be $\frac{35300}{3600}=9.8$ cubic feet.

From these data, following the preceding rules in the calculation of the dimensions of openings and flues, all the expenses of founding and carrying on the establishment will be kept within narrower limits than those which have attended its first application.

PRIMARY SCHOOLS.

61. The plans adopted should be designed to carry off and replace a volume of 400 to 500 cubic feet an hour for each child.

The ventilating-openings should be placed in or against the vertical walls of the two long sides of the room. It is only in case of great constructive difficulties that they may be confined to a single side. There should be as many of them as possible, and they should have a clear cross-sectional area that will give to the air carried off a velocity of more than 28 inches a second. They should connect with descending flues leading in the cellar or under the floor to a collecting-pipe, which, in most cases, should be carried directly to the foot of the ventilating-shaft.

The latter should be placed for its whole length beside the smoke-pipe of the heater, the heat from which will assist the draught. But this heat will not usually be sufficient to give proper activity to the draught even when the external temperature is very low, and it will be necessary to keep up a little coal-fire at the bottom of the ventilating-shaft in a grate detached from the walls.

If local arrangements prevent making the fire at the bottom, it may be made at the floor-level or at the top, keeping the ventilating-openings, however, in the vertical walls and near the floor.

The fresh air, warm or cold, should be admitted near the ceiling, and preferably parallel to its surface. In the season for fires, the air supplied by the heater should be mixed with the external cold air. The proportion of each may be regulated by means of registers easily controlled from the interior of the room, so that the mixture may have only the temperature of 85° to 95° at most.

The fresh-air openings should be arranged, if possible, along the whole length of the room, or at least be very numerous, and their section calculated so that the entering air should have a velocity of 40 inches a second, if it is directed horizontally parallel to the ceiling, or 20 inches, if it has a vertical direction.

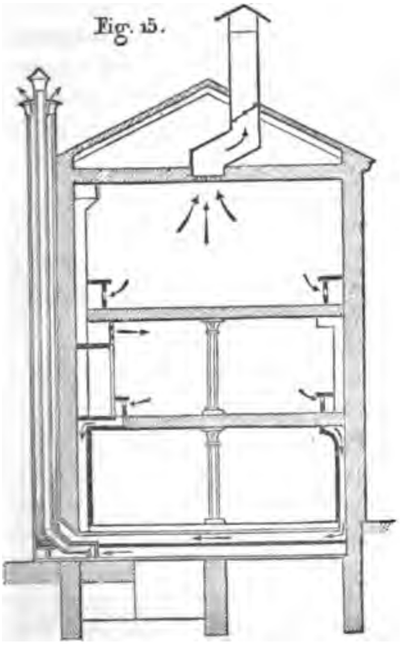


Fig. 15.

62. *Example. School in the Rue des Petits-Hôtels, Paris*, (Fig. 15.)—This school-building is intended for two perfectly distinct uses. The ground floor is used for the children's play-room. It is unnecessary to ventilate it, and a single stove is sufficient to warm it.

The second floor is occupied by the primary school kept by the Christian Brothers, and is divided into four rooms, intended for 400 children. The capacity of these rooms corresponds to a mean of 155 cubic feet for each child, which is about the proportion adopted by the city government, and seems to us totally insufficient; 250 to 280 cubic feet for each child appears the proper amount, especially as many schools for children are used in the evening as schools for adults.

The third floor is devoted to a drawing-school under the charge of a private professor, and contains 270 desks, of which 200 are in the main room, which, in the evening, is lighted by 90 gas-burners. The capacity of this room corresponds to 200 cubic feet to each person.

Ventilation in the two rooms during the day is limited to 350 cubic feet to each person, which necessitates the renewal of 140,000 cubic feet an hour in the second story and 70,000 cubic feet an hour in the third story.

The rooms are warmed by two heaters found by direct experiment to have a heating-capacity equal to 81 per cent. of the heat generated by the fuel,* and having proportions corresponding to 4½ square feet of heating-surface for every 1,000 cubic feet of room-area, supposed to be ventilated by a complete change of air twice an hour.

The warm air is carried to each floor by three vertical flues leading into a large and long pipe extending throughout the whole length of the rooms, which receives fresh air from without in order to regulate the temperature of the air admitted into the room. This air enters horizontally near the ceiling.

The volume of warm air, at a temperature of from 140° to 150° ascending in the flues before being mixed with cold air, was found to be, in the second story, 106,000 cubic feet an hour; in the third story, 73,000 cubic feet an hour; and this has been found sufficient to maintain in the rooms a temperature of from 60° to 70°, when that of the exterior air was 35° or 40°.

According to the instructions given to the builder, the foul air should have been carried away from the second story by thirteen flues, the proportions of which had been determined by applying the rule adopted in § 51, which fixes 28 inches a second as the velocity which the foul air should have in the first series of ventilating-flues, as indicated in the following table:

SCHOOL-ROOMS, (SECOND FLOOR,)

Numbers of the rooms.	Estimated number of children.	Volumes of air to be carried off—		Total sectional area corresponding to a velocity of 28 inches a second.	Number of flues and prescribed dimensions.	Total prescribed sectional area per room.
		In an hour.	In a second.			
1	90	32,000 cubic feet.	9 cubic feet	4 square ft	1 of 1 foot 7 inches × 1 foot=2.6 sq. ft. 1 of 1 foot 1 inch × 1 foot=1.1 sq. ft.	3.7
2	60	21,000 cubic feet	6 cubic feet	3 square ft.	3 of 1 foot 1 inch × 1 foot=1.1 sq. ft...	3.3
3	110	39,000 cubic feet.	11 cubic feet	5 square ft	4 of 1 foot 1 inch × 1 foot=1.1 sq. ft...	4.4
4	140	49,000 cubic feet	14 cubic feet	6 square ft	4 of 1 foot 5 inches × 1 foot=1.5 sq. ft...	6
	400	141,000 cubic feet.	40 cubic feet.	18 square ft		17.4

ART-SCHOOL, (THIRD FLOOR.)

1	200	71,000 cubic feet.	20 cubic feet	9 square ft.	4 of 1 foot 5 inches × 1 foot=1.5 sq. ft .. 3 of 1 foot 1 inch × 1 foot=1.1 sq. ft ..	6 3.3
						9.3

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* Annales du Conservatoire des arts et métiers, 6e vol., p. 325.

Note.—The builder actually gave smaller sectional areas to the flues; still the intended results have been secured.

In the first series of collecting-flues in each story, where the velocity is to be 39 inches a second, the sectional area should be—

	Square feet.
For the second story, amount to be renewed in 1 second = 39 cubic feet, sectional area	12
For the third story, amount to be renewed in 1 second = 20 cubic feet, sectional area	6

In the two collecting-flues terminating at the bottom of the general ventilating-chimney, the required velocity being 4 feet a second, their total sectional area was fixed at—

	Square feet.
For the second story	10
For the third story	5
	15

The latter flues carry the foul air to the bottom of the chimney, which is 56 feet high, and has a sectional area of 11 square feet. The two smoke-pipes being each 8 inches in diameter, or 2 feet in circumference, and having consequently 56×2=112 square feet of surface exposed to cooling, were not able, even in ordinary weather, to sustain the draught of the chimney, and a small auxiliary fire was deemed necessary. To this was given a surface of about 100 square inches, which, when burning 3½ pounds of coal an hour, carried off, on an average, 140,000 cubic feet of air an hour in the second story, and 70,000 in the third story. If the dimensions of the ventilating-flues given to the builder had been followed instead of being reduced to 16 square feet in the second story and 8 in the third, it is evident that the amount of air carried off would greatly exceed the prescribed amount, which shows that the rules which have been given allow for even serious defects in construction.

The observations made in this building in regard to the results of warming and ventilation lead to this important conclusion, that with well-made heaters and a properly-arranged system of ventilation, school-rooms with 350 cubic feet of air to each pupil may be comfortably warmed and ventilated by the use of no more fuel than is required for the injurious heat obtained from the cast-iron stoves used in most schools.

ADULT-SCHOOLS.

63. Similar plans should be adopted for adult-schools; the only change to be made consists in increasing to 500 or 700 cubic feet the amount of air to be carried off every hour for each person; or, in other words, to increase the size of the foul and fresh air flues.

NIGHT-SCHOOLS OF DESIGN.

64. These present a peculiar difficulty in changing the air and moderating the temperature, in consequence of the large number of lights

or gas-burners which they contain, which often produce a degree of heat in excess of that necessary to warm the room.

The general rule, which requires that the foul air should be drawn off near the floor, cannot be exclusively followed without causing currents of air heated from 85° to 95° to fall upon the students. It is, then, necessary to carry away the hot gases, the products of combustion, through the ceiling. But at the same time it is necessary to admit the fresh air, which in that case must be cool, at a certain height as far as possible from the floor.

But if the same room should also be occupied during the day as a study or drawing-room, and if it were then ventilated according to the usual rule by drawing the foul air off near the floor, it would be well at night to maintain that ventilation in order to assist the circulation and the descent toward the floor of a part of the fresh air brought in, of which to make up for the heating-effect of the lights, there should be a much greater amount than during the day.

Observations made in a school of design in Paris attended every evening by 200 to 240 scholars, and lighted by 90 gas-jets, consuming together 320 to 350 cubic feet of gas an hour, led for this special case to the following rules:

1. During the day, regulate the amount of foul air drawn off at the floor-level to about 530 cubic feet for each adult scholar and admit the fresh air near the ceiling.

2. For night-sessions, make escape-openings in the ceiling, the clear area of which should be calculated at about 88 square inches for every 1,000 cubic feet capacity of the room.

If there is no loft above the room in which the ventilating-pipes can be carried, special pipes may be placed at convenient points, removed as far as possible from those at which the fresh air is introduced. These pipes should be supplied with convenient valves, in order that they may be closed during the day, and the amount of the hot gases removed at night regulated.

3. Place in the two opposite walls of the room, or at least in one of them, at the height of 10, 13 feet, or higher, if possible, as many fresh-air openings as convenient, each supplied with a regulator to direct the air horizontally near the ceiling, the dimensions of these openings being calculated so that the volume of air admitted may be increased to six or eight times the total cubical capacity of the room, with an entering velocity of but 2 or 3 feet a second.

By means of these arrangements, drawing-schools may be made comfortable at night, which at present are almost like furnaces, and in which it becomes necessary to open some of the windows even in winter, notwithstanding the discomfort which may be experienced in consequence by the scholars nearest to them.

In the drawing-school just mentioned, the total amount of air carried off every hour was:

	Cubic feet.
April 4, 1866	367,600
April 6, 1866	430,000
Mean	398,800

which corresponds to a total renewal almost eight times an hour.

By means of this active ventilation, the temperature in the room has been maintained till 10 o'clock at night at 67° to 70° at 5 feet above the floor, and at 75° on an average at the ceiling, while, before the introduction of the means of ventilation mentioned above, it was, respectively, at the same heights, 80° and 90°.

65. *Plans to be adopted in schools already built.*—It too often happens that no plan has been provided in schools, and especially in night-schools, to produce even a partial change of air or to regulate the temperature, so that a stay in them is as unhealthful as it is unpleasant. There is, then, as we have said, no resource but to open the windows, and this is both uncomfortable and injurious to the scholars seated near them. These defects may, however, be removed, at least in part, in most cases by adopting the arrangements described in § 64 in the case of a drawing-school.

In order to carry off the hot gases arising from the lights, and prevent them from affecting the scholars, ventilating-openings should be placed near the ceiling. A number of ventilating-flues should be cut, the size of which may be calculated by the preceding rules; if possible, making them so large that the air may be renewed four or five times an hour. If, however, it is only possible to make one flue, it should be connected by means of a horizontal pipe, with a series of orifices in one of the long sides of the room. At the bottom of this flue should be placed either a little grate or three or four gas-burners, each consuming about four cubic feet an hour, in order to keep up the draught when the external temperature is too high for natural ventilation to be effective. The use of gas is in most cases of this kind more convenient than a coal-fire.

On the side opposite to that by which the foul air is carried off, a number of ventilators should be put in place of the upper panes of the windows, and arranged so as to be opened more or less as needed, in order to admit the fresh air as near as possible to the ceiling. By increasing and suitably arranging these openings, the injurious effects from the entrance of cold air will be avoided.

Arrangements of this kind have been recently adopted in the school at Saint Martin's Market, kept by the Christian Brothers, where there are about 100 scholars in the drawing-room every evening, light being furnished by a great many gas-burners. Simple wooden pipes carried up to the roof, and the employment of a few gas-burners, prove sufficient to carry off the foul air and gas, and indirectly to draw in fresh air through the ventilators placed on the opposite side to that by which the foul air is removed.

These means are far from being perfect, but their employment in school-buildings already built is almost always easy and inexpensive.

LYCEUMS AND COLLEGES.

66. In these institutions, where it is of the greatest importance to secure the change and purity of the air so as to promote the physical development of the youth, it is well to provide for this renewal at the rate of 500 cubic feet of air an hour for every child under 12 or 14 years, and 900 cubic feet for every person 15 years old or older.

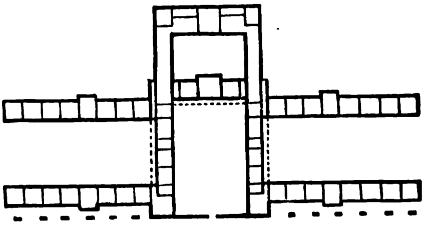
The class and study rooms having to be warmed and ventilated constantly during the day, and the sleeping-rooms during the night, it is best to make use of such forms of heating and ventilating apparatus as include all the rooms of the same building. Those employing hot water should always be preferred, notwithstanding their greater first cost, because that is largely compensated for by their regularity of operation, and also by their economy of fuel.

Cast-iron stoves, too often used in these establishments, are extremely injurious, not only because they heat too irregularly, and often to excess, but also because the iron, a porous metal, produces a noticeable and dangerous alteration of the air.

67. *Application made at the Toulon Lyceum.*—M. Laval, one of the most skillful of French architects, and one who has for several years past been specially occupied with questions relating to the healthfulness of habitations, has made a very happy application of the principles just mentioned in the new lyceum at Toulon, which he designed. Some details in regard to it will prove of interest, since they will serve both as an exemplification of the rules and as a model to be followed in similar circumstances.

In this establishment, there is a main court-yard, giving access to all the rooms, (Fig. 16.) This communicates right and left, by means of passages, with the halls, studies, and class-rooms of the first and second divisions. At the rear, in a separate building, are placed the natural-history collections and the physical apparatus. Behind this building is the hospital-court, around which are, on the ground-floor, the dining-rooms and the kitchen, and, on the second floor, the infirmary with its bed-rooms.

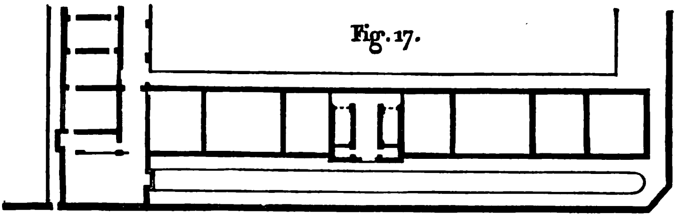
Fig. 16.



The lyceum will accommodate 300 boarding-scholars, occupying during the day six study-rooms and at night ten bed-rooms. There are also twenty-two class-rooms, each intended for forty scholars on an average, which should be ventilated at the same time as the study-rooms. All the class-rooms and studies on one side of the staircase have together a content of 42,000 cubic feet, which is to be ventilated by one apparatus; and the two sleeping-apartments placed above these rooms have each a capacity of 37,000 cubic feet, or together 74,000 cubic feet. The chimney and the ventilating-apparatus, which will be described hereafter, then serve during the day to ventilate the recitation-rooms, containing 42,000 cubic feet of air, and during the night the bed-rooms, containing 74,000 cubic feet.

The class-rooms and study-rooms in each division are placed on the ground-floor of large buildings, of which the second floor contains the corresponding bed-chambers. A fine staircase, placed near the middle of each wing, gives access to the rooms. Fig. 17 shows the general arrangement of the ground-floor of one of the four similar buildings.

Fig. 17.

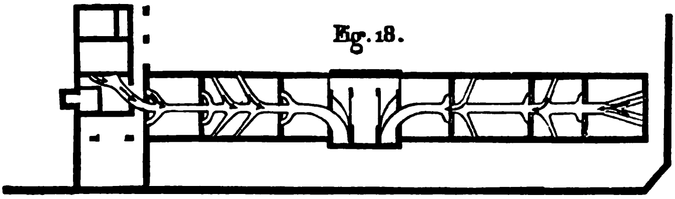


The climate of Toulon is so mild that no arrangements for heating had to be provided, but ventilation appeared still more necessary under the southern sun than almost anywhere else.

M. Laval took as a basis for the calculations and the dimensions he adopted the renewal of a volume of air of 900 cubic feet an hour to each person, which seems amply sufficient.

The ventilating-flues were made in the thickness of the walls of the rooms on the ground-floor and the sleeping-rooms; their number as well as their areas were calculated by allowing a velocity of about 28 inches a second to the air passing into them, (Fig. 18.)

Fig. 18.

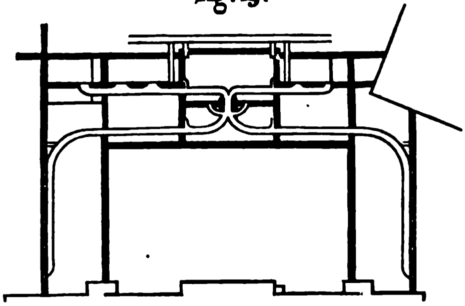


The general system adopted is that of a descending draught, and the ventilation is confined during the day to the lower rooms and at night to the sleeping-rooms.

The descending pipes, which receive the foul air at each side of the front rooms, unite under the floor in two central collecting-pipes, placed right and left of the staircase, each terminating in a ventilating-chimney, of which there is one on each side of the staircase.

Each story has its ventilating-pipes and its speci

Fig. 19.



and the two
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other, as seen
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ventilation of
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that for the cla

A coke-stove, only filled every twelve hours, the drau
be regulated at will, is placed at the bottom of each
rol the ventilating-current.

Such are the simple and inexpensive arrangements
four buildings containing the study-rooms, class-room
ries.

The building containing the dining-rooms and the inf
lated in a similar way; but for them M. Laval has skillfu
the waste heat from the cooking-range, in which fire is k
day.

In the dining-rooms, the tables are arranged on the s
an outer wall, pierced with many windows, which admit
from the infirmary-court. The ventilating-openings are
face of the opposite wall in the space between the tables.
flues lead into collecting-pipes, which carry the foul air to
the kitchen-chimney; and this is always warm enough
sufficiently powerful draught.

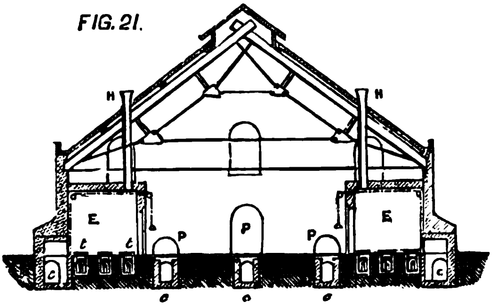
For the infirmary, situated on the second floor, the arra
similar; and as the dining-rooms only need to be ventila
hours, the heat of the kitchen-range and that of the fires
paring decoctions and poultices, not only serve without exp
off the foul air, but also to heat the baths required in the es

Introduction of fresh air.—The mildness of the climat
allowing, as has been said, artificial heat to be dispensed
troduction of fresh air does not present any difficulty, and n
is necessary, except to prevent the draught from becoming
M. Laval has provided for that by placing ventilators in p
upper panes in the window to throw the air toward the c
valve allows the amount of opening to be regulated when t
the draught renders it necessary.

In the sleeping-rooms, he has added convenient arrangeme
renewal of the air during the night; the opening of little do
under the window-ledge allowing the air to flow out at the
and under the beds in order better to purify the room.

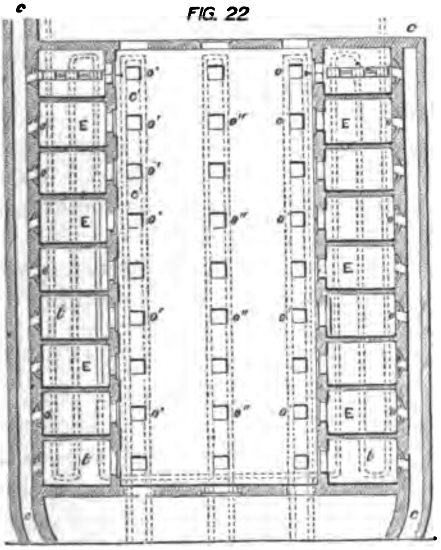
These are all ventilated by means of a large central chimney, 7 feet in inside diameter and 118 feet high, which receives the hot air from the furnaces of the steam-boilers, and, when needed, additional heat from a separate fire. Along the outer face of the side-walls of each building extends a subterranean passage-way of masonry, (c c, Figs. 21, 22,) 2 feet square, leading to the base of the chimney. Wherever the phosphorus is placed, an opening is made either in the walls or in the floor, communicating by a small pipe with the underground passage so as to carry off the injurious vapors without allowing them to spread in the shop.

FIG. 21.



Special arrangements differ according to the nature of the work. Thus, where the tips are prepared, a wide and shallow funnel is used, in which the draught is increased by the flames of the melting-fire.

FIG. 22



The shop for the dipping and drying operations, which are the most dangerous, is particularly well ventilated. The general arrangement is shown in the two figures, (21, 22.) The building is 66 feet by 49 feet. Along the two sides are placed the drying-chambers E E E, 18 in number, each being 6 feet wide, 16 feet deep, and 7 feet high to the spring of the ceiling-arch, and 9 feet to the crown. They are connected with the ventilating-tunnel c c by a triple row of openings, o, o, o, 10 inches by 5 inches, at the floor-level, and receive the external air either by chimneys extending above the roof or by openings, 9 inches by 6 inches, placed at the bottom of the iron doors of the drying-rooms, and taking air from the main hall. The doors are 6 feet high and nearly 3 feet wide. The drying-rooms are heated by three rows of 2-inch steam-pipes placed under the floor. The channels in which these pipes are placed should receive cold air to be carried directly into the drying-chambers. Valves worked from the outside of the chambers control the admission and removal of air, which should enter with a temperature of about 140°, that of the chamber not exceeding 95°.

In front of each range of drying-chambers there is a small railroad, extending from the melting-room to the warehouse. An iron car takes the prepared composition, and carries it to the drying-chambers in succession. Before each door or station, an orifice, o′ o′, made in the floor, exerts a powerful draught, which draws the vapors into the exterior lateral tunnel. The dipping is quickly done, and the frames are immediately placed in the drying-chambers, the iron doors of which are carefully closed.

The middle portion of the building is reserved for boxing. Under the tables are also placed ventilating-openings, o″ o″. The filled boxes are finally put in the car and carried to the warehouse.

The main passage-ways c c and c′ c′ enter separately into the base of the chimney, and are kept apart there by small vertical walls, in order to prevent contrary currents and to allow them to be regulated at will.

By means of these arrangements, all smell of phosphorus in the main factory is prevented, and the men who work there are no longer exposed to necrosis. By taking the additional precaution of having them frequently visited by physicians, and of maintaining proper rotation in the hands employed in the different shops, they will be completely freed from this terrible disease.

MANUFACTORIES.

72. In some manufactories, it is essential for the quality of the products that the internal temperature be not allowed to fall below a certain limit; or, in other words, that the manufactory be heated even in spring and fall, and that the windows be kept closed. From this it follows that the air, not being changed, becomes gradually saturated with vapors and cutaneous emanations, and becomes at last unhealthful.

The workmen being thus kept continually perspiring, although they take off part of their clothing, go out afterward into the cold air, and often contract serious affections of the respiratory organs.

The conditions of the manufacture may be secured at the same time with those of hygiene by a strong ventilation, which shall constantly furnish fresh air of the necessary degree of temperature and even of moisture while regularly carrying off the foul air. With this change of air, a temperature of 75° or 77° will be found comfortable, and the workmen no longer be continually perspiring in an atmosphere constantly becoming more impure.

The rules to be observed are the same as those mentioned before, and a complete change three or four times an hour will usually be sufficient.

The escape-steam from the engines is in such cases usually employed for heating, and it may be so regulated as to give the desired temperature to the fresh air, and the smoke-stack of the steam-engine will, without additional expense, maintain the draught required for carrying off the foul air.

In cases where the smoke-stack would be otherwise too small, the draught may be increased or entirely produced in it by heating it by steam, or by placing a steam-jet in it as in a locomotive.

73. *Workshops in which dust more or less dangerous to breathe is produced.*—In a large number of occupations, the division of the raw materials produces dust, which may be fine or coarse, heavy or light, harmless or injurious, and which it is important to remove from the workman and carry out of the building.

In most of these cases, ventilation, by means of a draught produced by heat, would be insufficient, at least unless it were made extremely powerful by an intense heat. It would be sufficient for light dust of very finely-divided materials, but for heavier dust, such as that produced by grindstones, it becomes necessary to use mechanical apparatus to force, through suitably-arranged pipes, currents of air at a proper velocity, which trial alone can determine.

In winter, when artificial heat may be required, as well as in summer, when it is unnecessary, it is essential that the discharge-openings should be placed as near as possible to the machines which produce the dust or emanations, and that the openings for admission of fresh air should, in general, be far off, in order that the velocity should gradually increase from the point of admission to that of exit.

But if the shop contain few workmen, if it is naturally sufficiently well aired, and if it is only required to carry off the dust as directly and quickly as possible, it would be better that the air be admitted under the cover which should completely surround the apparatus or the machine above the point where the dust is produced, while the draught is applied below the same point and the dust is carried directly out of the building.

The preceding remarks apply especially to those shops in which but a few detached instruments are used.

74. *Cutlery-works.*—One of the most dangerous occupations is that of the cutler. When proper precautions are not taken, the dust arising from the grindstones, which are used dry, enters into the respiratory passages.

These dangers are reduced and almost removed by the following arrangements:

75. *Grindstones used wet*, (Figs. 23, 24.)—The stones should be surrounded as completely as possible by a movable covering of wood or sheet-iron, which should have no opening in front but what is absolutely necessary for the work.

In order to avoid the choking-up of the ventilating-pipes, it will be necessary to provide special discharge-pipes for the water, somewhat as indicated in the figures, according as the stones are partly below or entirely above the floor.

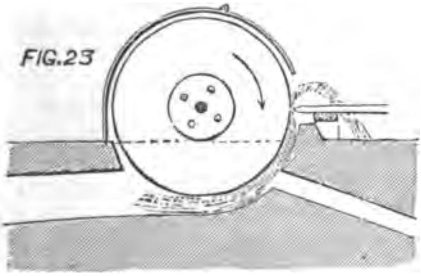


FIG.23

The passage intended for carrying off the dust should be placed underneath the stone, and beyond the point where the work is applied, regarding the direction of the motion. It should have a breadth a little greater than that of the stone, and a depth of eight inches, at most, for the largest stones. A sliding door serves to close it whenever dry dust is not produced. The water-discharge pipe should also have a valve, which may be closed when water is not used, and when it is desired to carry off the dust produced when the stone is trued.

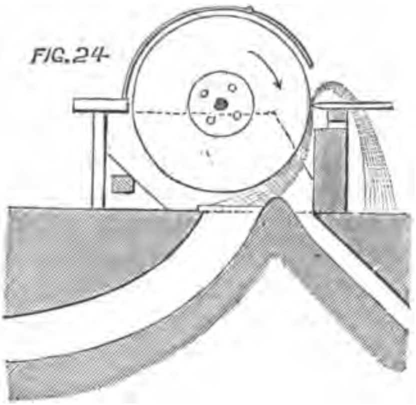


FIG. 24

The separate air-tubes from each stone lead to a collecting-pipe 16 inches by 12 inches, to which they are united by couplings.

If there are only four or five stones in the works, a single collecting-pipe will be sufficient, and the blower should be placed at the end. But if there are eight or ten stones in one line, it will be better to place a second collector, 16 inches by 12 inches, in the middle of the length of the first, and perpendicular to its direction. The blowing-apparatus should be placed in the extremity of the second pipe.

Finally, if there are two long parallel rows, with eight or ten stones in each, they should also be connected with the second collector, or with a third, 16 inches by 20 inches, communicating with the ventilator.

In all these arrangements, movable valves should be placed at the junction of each of the pipes, to prevent the circulation of air in those which are not used at any time for carrying off the dust, since it is not intended to ventilate at the same time all the stones of the same mill. The valves placed at the head of each pipe should also be closed when it is not being ventilated.

But the greatest difficulty in rendering these places healthful, as in most other cases, arises from the carelessness of the workmen, and in the negligence of the foremen, who do not insist on the strict observance of the regulations.

76. *Application.*—At Châtellerault's armory, the results obtained by Peugeot & Bros., of Valentigney, (Doubs,) in their hardware manufactory, were made use of, blowing-machines having been placed in two shops containing each—

Main stones, 8 inches in diameter	2
Grooving-stones, 4 feet in diameter	16
	18

A fan-blower, 31 inches in diameter and 16 inches wide, parallel to the axis, and having a central opening 11 inches in diameter, making 900 to 1,000 revolutions a second, and requiring at most 8 to 10 horse-power to run it, easily removes all the dust produced during the truing of the two main stones and twelve of the grooving-stones, the other passages being closed.

The axis of the fan-blower is placed in the line of the last collecting-pipe, and is closed on the side opposite that pipe; the air carrying the dust is expelled at the outer circumference, which is entirely free.

Notwithstanding the success obtained in large works by the arrangements mentioned above, it would be better in all cases to separate the workmen into small shops of two stones each, each furnished with special ventilating-apparatus similar to that which we have described. Recent trials seem to show that ventilation obtained by forcing in air would in this case prove very satisfactory.

DRYING-CHAMBERS.

77. The general arrangements which should be adopted for drying-chambers are in conformity with the rules previously given. The air should flow in at the top; and, as in this case, it is always very hot, it enters of its own accord, but it is necessary that it should be introduced uniformly. The openings for the escape of the air saturated with moisture should be placed near the floor and on the whole circumference of the room. It is sufficient to connect the ventilating-pipes with the base of the chimney of the heating-apparatus.

The temperature which it is necessary to keep up in the drying-chambers depends upon the nature of the articles to be dried. For vegetable substances and flour, it need not exceed 105° or 110°; for linen and cloth, 158°.

The particular conditions in each application may lead to some modifications of the general rules. Linen-drying rooms present a case which it is well to specify.

LINEN-DRYING CHAMBERS.

78. The arrangements for these useful accessories (Figs. 25, 26) to large bleaching-establishments have been carefully studied by Bouillon, Muller & Co. The linen is carried to the wringing-machine, which removes from it a great part of the water which it contains after having been washed; but it still retains about one-third of the total weight when it reaches the drying-room. When it is hung vertically, this water accumulates principally at the lower part, which therefore becomes hard to dry. Again, when the air enters through a single opening at the upper part of the chamber, the interruption to the circulation of hot air caused by the linen which hangs in vertical bands and the force of the draught which tends to draw the air directly toward the ventilating-openings prevents the drying from proceeding uniformly, especially in large drying-houses. The observation of these irregular effects has led Bouil-

lon, Muller & Co. to adopt, for their latest linen-drying chambers, the following arrangements:

The chambers of which a drying-room is composed (Figs. 25, 26) are very small, and are at most 10 feet long, 4 feet wide, and 5 feet high, or 200 cubic feet in area.

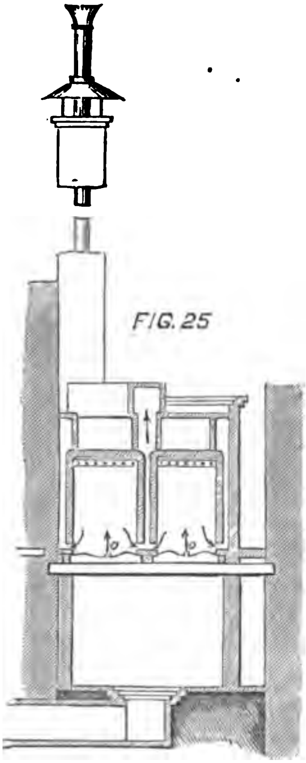


FIG. 25

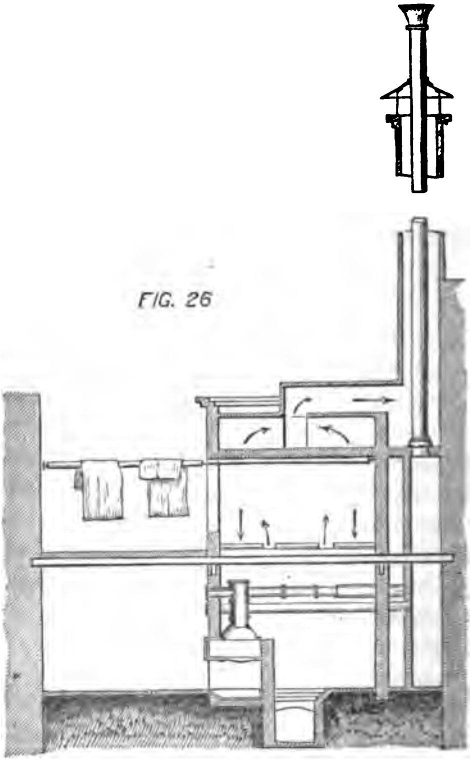


FIG. 26

The floor is composed of two pieces of curved sheet-iron, forming at the same time the top of the warm-air chamber of the heater below. These two pieces of sheet-iron leave an opening o between them, which extends the whole length of the drying-room, and through which the hot air is introduced, which, after having dried the bottom and dampest part, rises with the vapor it produces toward the ceiling, and descends again to the ventilating-openings, arranged near the floor along the whole length of the side-walls, the latter being made hollow and provided with pipes leading to the chimney, which also contains the smoke-pipe, as shown in the figures.

The linen is arranged outside of the drying-chamber on brass tubes sliding on iron rods extending the whole length of the chamber. These rods and the tubes which they carry are placed at the middle of a narrow door of the same height as the drying-chamber, which is only opened when the wet linen is put in, or the dry taken out.

Each chamber contains 8 rods. They receive, in two charges, 106 pounds of damp linen, in which 35 pounds of water remain after they have been wrung.

The evaporation of these 35 pounds of water is effected in an hour by the consumption of about 11 pounds of coal.

The temperature of the chamber is kept at 158°, and the amount of air passing into the chamber varies from 35,000 to 42,000 cubic feet an hour.

Four chambers, with their 32 rods, are attended to by one woman, who fills and empties them.

According to the rules previously given, the 35 pounds of water evaporated, requiring $35 \times 1170 = 40950$ units of heat, and the 11 pounds of coal giving 159,000, the calorific effect of the apparatus is equal to $\frac{40950}{159000} = .26$.

The same result was also obtained from some experiments made for seven years at La Saltpetrière, in which, with a consumption of 6,415 pounds of coal, 18,940 pounds of water were evaporated, the calorific effect in these experiments was found to be .24.

POWDER-DRYING ROOMS.

79. In the case of powdered materials spread out to a certain thickness, it is often necessary to use blowers which drive the air under a table, closed on all sides, the top of which is formed of wire-gauze, on which the substances to be dried are placed.

Thus, in powder-mills, the air driven under the gauze has ordinarily a pressure measured by a column of water $\frac{3}{16}$ or $\frac{1}{4}$ inch high, and a temperature of 112° to 140°. The thickness of the layer of powder varies from $\frac{1}{2}$ to 3 inches, according to its nature. The air is heated to the proper temperature by means of water or steam pipes.

Although, in such cases, blowers are most frequently used, the same result may often be obtained by means of a well-regulated draught alone. At the powder-mill of St. Chamas, a drying-room, warmed by hot-water pipes placed under the table, and supplied with a chimney containing a hot-water vessel to produce a draught, has worked satisfactorily even in the case of blasting-powder containing 8 or 9 per cent. of water.

BARRACKS.

80. The volume of air to be renewed every hour for each individual being given at 1,000 cubic feet during the day, and 1,400 to 1,800 durng the night, the proportions and arrangements of the openings will be determined by the preceding rules.

But it is principally, and it may be said solely, during the night that te ventilation of the barrack-rooms is necessary, since, during the day, te soldiers are almost always out of it.

The heating of these rooms during the day is intended only to enable those who return from duty, after getting wet, to dry their clothes and shoes; for this purpose, ventilating fire-places are preferable to sheet-iron stoves, because, in addition to the radiant heat they give out, they have in this case the advantage of carrying off the vapor arising from the damp clothing, which would make the room unhealthy and disagreeable. The fire never needs to be kept up long, and it cannot be counted upon to produce a constant change of air.

If natural ventilation alone be employed, it is necessary, according to observations made at the Bonaparte barracks in Paris, that the openings for the admission and discharge should be proportioned as follows:

Area of openings and flues to each bed in summer: discharge, 31 square inches; admission, 62 square inches.

In winter, spring, and autumn, these proportions would be excessive, and means should be provided for closing part of the openings, so as to confine the circulation of air within proper limits. But the regulation of the registers or valves should not be left to the discretion of the soldiers.

The necessity of preventing the soldiers, in their ignorance, from stopping up the escape-openings requires that in this case the rule should be violated which prescribes that these should be placed near the beds and the floor, as it will be necessary to place them near the ceiling, as well as those for the admission of fresh air.

The first should open above the space between the beds, and the flues should be placed near the smoke-flue or should receive the stove-pipe when stoves are used. The second, intended for the introduction of fresh air, are also placed near the ceiling, and made in the face of the opposite wall.

This arrangement presents the advantage that if, as often happens in ventilation due simply to the action of natural temperatures, the direction of motion changes so that the escape-pipe becomes that of admission, no discomfort is experienced by the men, who in both cases are removed as far as possible from the openings.

These precautions will be completed by placing horizontal or inclined shelves under the openings, which will force the air always to remain nearly or quite horizontal in entering or passing out.

There is no reason to fear that the air flowing in will immediately rush to the escape-openings before circulating through the rooms; the difference of internal and external temperature will always enable the circulation to be maintained.

81. *Utilization of the lost heat of cooking-stoves.*—In most barracks, th cooking-arrangements of the companies which occupy that part of th building reached by one staircase, and often also all those used for whole wing, are collected in a single room on the ground-floor, devote to this purpose. There, separate stoves are used, in cooking, for eac company, squadron, or battery. Beside these stoves, strongly heat twice a day, or even in their chimneys, it would be very easy and ine-

pensive to place hot-water receivers in the form of a drum, or of pipes such as are often used in heaters, into which hot-water pipes should be tapped, and then carried vertically in the foul-air flue leading from the rooms, thus securing a change of air at all times and without expense.

In this way, also, baths might be supplied, which would be of great service for soldiers' hospitals. Ventilation being, as has been said, much more important at night, when all the men of one mess are together, than during the day, when most of them are out of doors, the registers —the regulation of which should only be made by the order and under the direction of the adjutant of the week—will serve to check or prevent escape of air during the day, so as to accumulate heat in the flues for the night.

HOSPITALS.

82. *General plans and dimensions to be adopted for the ventilation of hospitals.*—It is only proposed in what follows to give the proportions of the principal parts of the flues and pipes which it is necessary to use for the ventilation of hospital-wards, in order to secure the removal of vitiated air and the introduction of fresh air.

These proportions apply also to the different plans which local conditions may cause the architect to adopt.

The amount of air to be renewed in the sick-rooms may vary, according to circumstances, from 2,000 to more than 3,500 cubic feet an hour for each bed; 2,800 will here be taken as a basis for the calculations.

When local conditions permit, the foul air should be drawn off through descending passages; openings into them being made behind the head of the beds, at the floor-level, but in the vertical walls, to be in number at least equal to one for every two beds in ordinary hospitals, and one to each bed in lying-in hospitals.

When a hot-water heating-apparatus is used, and when the plans adopted as well as the proximity of chimneys permit, the waste heat from the small heaters and hot-water tanks used in the hospital should be made use of to assist the draught.

But it is not necessary that the use of these little reservoirs, which have but a small capacity, should lead to the exclusive adoption of the up-cast draught, as L. Duvoir has done, and which is less advantageous.

83. *Advantages of the down-cast draught.*—It will be remembered that the arrangements required by the down-cast draught lessen very much the weakening of the walls by the passage of ventilating-flues.

Thus, for a building with rooms on three floors, as in the case of Lariboisière Hospital, the piers of the third story are not pierced for any flue, because their own commences at the floor; those of the second story are only pierced by a single flue coming from the third floor; and those of the ground-floor only contain the two flues belonging to the second and third stories.

The thickness of the walls being greater at the lower stories, the flues would always be proportionally less injurious with descending draughts than with ascending draughts, the latter requiring the largest number of flues to be made in the upper stories, where the walls are thinnest.

Figs. 27, 28, which represent only the general features, show the advantages presented by down-cast draughts over up-cast draughts as regards the weakening of the walls by the ventilating-flues. The down-draught, besides, as we have said, renders it easy, in order to give due force to the draught, to make use of the entire height of the main ventilating-chimney, to the bottom of which the flues are connected. It forms a very economical means of utilizing the heat expended in producing it.

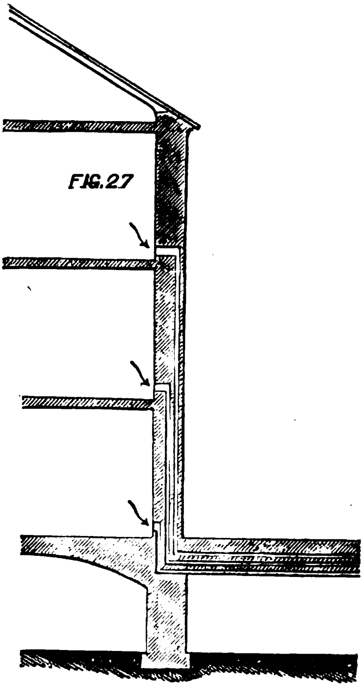


FIG.27

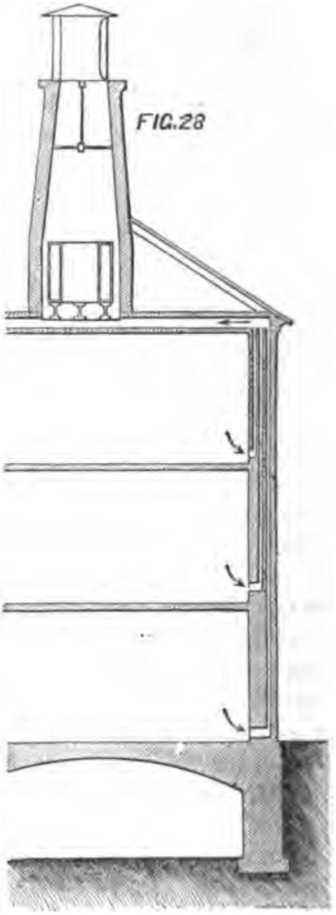


FIG.28

For a building of a construction similar to that of Lariboisière Hospital, where the piers at the ground-floor have a mean width of 10 feet and a thickness of 2 feet 7 inches, or 26 square feet of sectional area, if the two flues are carried from the second and third stories to the basement, they require, at most, in the walls—including the partition between them and even the interior brick lining—a space $2 \times 1' + 1'' = 2'\,1''$ broad, and $9'' + 2'' = 11''$ deep, or a total sectional area of 1.9 square feet; that is to say, one-fourteenth of the total sectional area of the pier, which could not have any effect on the stability of a well-constructed building with a good foundation.

On the contrary, if the ventilating-flues be carried upward, the piers of the third floor, which are only 10 feet by 2 feet=20 square feet in sectional area, would be pierced by three flues, making a channel $3\times1'+3''$ $=3'\ 3''$ broad, by $11''$ deep, or $2'\ 9''$ sectional area, equal to one-seventh that of the masonry. This would not be admissible.

In cases where the flues for the introduction of fresh air have also to be provided for in the piers, though this can sometimes be avoided in hospitals the wards of which contain only twelve or fourteen beds, it will be seen, then, that the enfeebling of the walls by the passage of all the flues will not endanger the solidity of properly-built walls.

84. *Cases where the walls have not sufficient thickness.*—When the nature of the materials used or local circumstances do not permit of giving the walls sufficient thickness to allow of cutting flues in them with safety, ventilating-shafts may be made projecting from the walls in the interior of the rooms, making them of light brick work. Then, to diminish as little as possible the available breadth of these rooms, and to prevent hurting their appearance, the depth of these flues should be restricted by making them occupy almost the entire breadth of the piers.

85. *Arrangement of the ventilating shafts.*—The necessary arrangements should be made to prevent ventilating shafts or flues from being crossed by the beams or joists of the floor, which can easily be avoided by the use of trimmers.

If there are no cellars under the buildings, which is not indispensable, sufficiently large vaults should be made to give the necessary area of passage-ways, and these should be covered on top, as well as the floor of the first story, with a coating of tar-concrete, to protect it from moisture. If any difficulty be encountered in carrying the ventilating-flues below the floor of the first story, they may stop at this floor. It is only in exceptional cases, or in buildings already constructed presenting peculiar obstacles, that the flues should be carried from below upward in the upper floors or in the roof.

In every case, the discharge-flues corresponding to beds placed on different floors one above another, should be kept separate in their vertical course and not united in groups in partial horizontal conductors, unless separated by partitions for an extent of 10 or 12 feet beyond the outlet of those which are the nearest to the main ventilating-chimney, in order to prevent as far as possible the establishment of communications from one story to another.

86. *Dimensions of ventilating-flues and collecting-pipes.*—The sectional area to be given to the first ventilating-passages should be calculated on the basis of the renewal of 2,800 cubic feet of air an hour, or $\frac{2800}{3600}=.78$ cubic foot a second for each bed, and at a mean velocity of 2.3 feet a second, which would give $\frac{.78}{2.3}=.34$ square foot, or 49 square inches of

sectional area for each bed; and as it is admitted that in common hospitals it will be sufficient to have one flue to every two beds, it will be necessary to have 98 square inches sectional area, or to make the flues, say, 9 inches deep by 11 inches broad.

For lying-in hospitals the volume of air to be renewed being 3,500 cubic feet an hour to each bed, or 98 cubic feet a second, the sectional area of the flues should be .43 square foot, or 62 square inches.

In the first collecting-pipes, which unite the flues by groups, a mean velocity of from 3 to 4 feet a second is allowed, and the sectional area may be calculated on this basis and according to the number of beds which it is necessary to ventilate.

The second collecting-pipes, if any are formed to receive the vitiated air from the preceding, should be proportioned by supposing a mean velocity of from 4½ to 5 feet a second.

87. *Ventilating-chimney.*—Finally, in the main ventilating-chimney, it is granted that the mean velocity should be about 6 feet a second, and that in the upper part it should be at least 6½ feet a second, in order not to be checked by gales.

At the bottom of the chimney there should be an iron grate, surrounded by a brick rim, completely isolated from the walls, in order that the air coming in from the collecting-pipes may partly circulate around it, and only become warmed to a moderate though sufficiently high temperature.

In every case, there should be arranged a direct passage opening to the outside at the base of the chimney, through which the fireman may feed the fire.

If obliged to perform the work in the foul-air gallery, he would run the risk of being suffocated, or at least of experiencing much discomfort.

The mean interior temperature of the chimney should in all cases exceed that of the external air by a constant difference of 36° to 45°, in order to give to the draught the same force at all times. The ventilating-fire should be much more energetic in summer than in winter.

Similar methods proportioned upon the same data should be adopted in cases where the arrangement of the different wards leads to the use of a single ventilating-chimney for a large number of buildings.

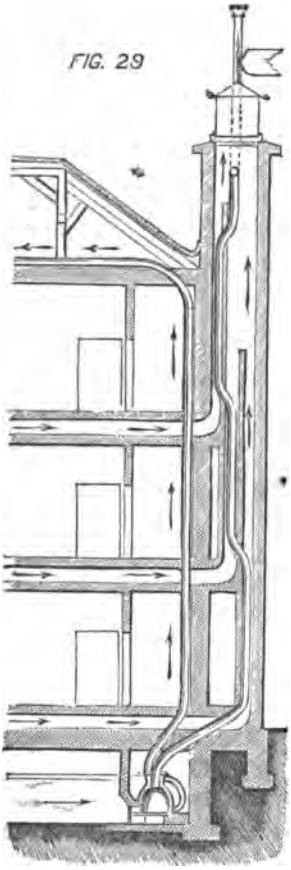
Means for maintaining the regularity of the fire will be given further on.

88. *Cases where the foul air may be drawn off at the floor-level.*—When the general plan adopted for the building includes a veranda on one side, the foul air may be drawn off at each story, to avoid the necessity of making vertical flues in the walls, by placing the ventilating-chimney at some point in the veranda, and carrying the ventilating-pipes into it, placing them between the floor-beams. (Fig. 29.)

A similar arrangement will render it easy to improve the ventilation by using a part of the heat from the kitchen and bath boilers, the hospital-stoves, smoke-flues, kitchen-ranges, &c.

In such a case, each ward would have a main ventilating-chimney carrying off the foul air from each story in flues separated from each other as far as to the top of the upper story. At the bottom of each of the collecting-flues may be kept a little auxiliary heater, to be used only when necessary in order to obtain a sufficiently powerful draught.

FIG. 29



It should also be understood that in every case the interior surface of the flues should be covered with as smooth a coating as possible, to diminish the resistance to the motion of the air, and that the openings should be arranged so as to permit of cleaning the flues at least twice a year, in order to remove the cobwebs and other obstacles which would interfere with the circulation of air.

In general, it would be well to place on top of the ventilating-chimney a cowl, which the wind would keep with its mouth away from the wind, so that strong winds would assist the draught, instead of checking it, as they would do without this precaution.

The proportions and the general arrangements which have been indicated should also be observed when it becomes necessary to draw off the foul air either at the level of the floors, as just mentioned, or at the top of the buildings, as will often occur, especially in the case of existing buildings.

Whenever local conditions permit, the smoke-flues of the heating-apparatus should be carried up in the main ventilating-chimney, in order to use the heat they give out. They should be made of cast iron and kept separate.

89. *Utilization of the waste heat of laundries and kitchens.*—The furnaces of the laundry-boilers should, if possible, be placed at the base of the ventilating-chimney, in order to assist the ventilation by means of the heat given out in the furnaces by the gaseous products of combustion.

90. *Application of the preceding rules.*—Let us take the case of a hospital of 100 beds, containing two wards, with but one ventilating-chimney, having two stories, containing together 50 beds in each ward there being four halls with 12 beds, and two rooms with one bed each.

Under these conditions, each hall will contain six beds on each side, and there will be three ventilating-flues, 100 square inches in sectional area, or $8\frac{1}{2} \times 12$ inches.

The vertical flues should be carried under the floor of the ground-story, and joined to the first horizontal collectors intended to furnish passage to the air brought by the first, and each should carry off $12 \times .78 = 9.36$ cubic feet a second with a velocity of 3.28 a second. They should then have a section of $\frac{9.36}{3.28} = 2.86$ square feet, or be 1 foot 8 inches square, for example.

One of these flues, which would also ventilate the two single-bed bedrooms, or $14 \times .78 = 10.92$ cubic feet, should have a sectional area of $\frac{10.92}{3.28} = 3.34$ square feet, or should be 1 foot 8 inches by 2 feet.

If these pipes do not lead directly to the foot of the chimney, and if the general arrangements adopted render it necessary to carry the first collecting-pipes into a second collector, the volume of air which the latter will be obliged to pass will be $50 \times .78 = 39$ cubic feet, with a velocity of 4.6 feet a second. Its transverse section will then be equal to $\frac{39}{4.6} = 8.50$ square feet, and it may have the dimensions 2 feet 10 inches by 2 feet 10 inches.

If the main ventilating-chimney should have to carry off the foul air of both wards, or that from 100 beds = 280,000 cubic feet an hour, or 78 cubic feet a second, with a mean velocity of 6 feet a second, its internal sectional area should be $\frac{78}{6} = 13$ square feet, and its mean internal diameter 4 feet. At the upper part, this diameter should be reduced to 3 feet 10 inches to make the velocity there $6\frac{1}{2}$ feet a second.

91. *Introduction of fresh air.*—The openings for the introduction of warm or cold air should always be placed near the ceiling, and distributed as uniformly as possible throughout the whole extent of the halls in the proportion of one to every two beds if possible, or at least one to every four beds.

When they are made in the walls, they should be furnished with registers in the form of slats inclined 20° or 25° to the horizon in order to force the air in that direction toward the ceiling.

The transverse section of the vertical or other flues should be calculated so that the air will traverse them with a velocity not exceeding 3 or 4 feet a second. That of those through which the air flows immediately into the room should be determined by the condition that the entering velocity should not exceed 3 or 4 feet a second.

In the case where the air flows from above vertically downward, through openings in the ceiling itself, which may take place where double floors are used or where a loft serves as an air-chamber, the sum of the clear sectional area of the passages should be calculated on the condition that the velocity should not exceed 18 inches or 2 feet a second.

When ordinary heaters are used for heating, the warm air which they supply should be introduced before its admission into the halls into a mixing-chamber, where a sufficient quantity of external air is also admitted, in order to moderate as required the temperature of the air supplied to the rooms.

To secure the proper mixture of external air with the warm air from the heating-apparatus, it will be necessary to keep the fresh air above the current of warm air by means of more or less wide partitions. It will then happen that, as the first or denser stratum tends to fall while the second or lighter stratum rises, the mingling will necessarily take place. This applies as well to separate and direct openings for the admission of warm and fresh air in halls as to those for the admission of air into the mixing-chambers. The partitions should be made of brick laid flat, and be at least two inches thick.

During the period of fires, the temperature of the inflowing air should, for healthful ventilation, differ as little as possible from that intended to be kept up in the halls, which should be uniformly about 60°.

The mixing-chambers should be formed either in the floor above the the heaters or in the corridors or small rooms.

Registers should be placed in the mixing-chambers, to permit the temperature of the air supplied by them to be regulated at will.

Similar arrangements should be made when hot-water or steam heating-apparatus is used.

If the hospital stands by itself and is in a healthful location, the external-air supply may be taken either at the ground-level from the middle of a lawn or flower-bed, as at Vincennes and the lying-in hospital at St. Petersburg, or at the level of each floor.

Descending currents will not be required to carry the air from a certain height, except in cases where the proximity of more or less unhealthful buildings would lead to the fear of infection in the air at the ground-level.

In that case, the chimney for bringing in air should be placed as far as possible from that for carrying it off. The sectional area of the former, and in general that of all external openings for the admission of air, should be calculated so that the velocity of admission should not exceed 2 feet a second, in order that the draught produced in the vicinity of the openings may only extend a small distance.

The openings for the admission of air entering at a considerable height should be provided with valves or doors, which may close them if required.

In summer, when the action of the draught in drawing in fresh air is not assisted by the increase of temperature which the heating-apparatus gives to the fresh air in winter, there should be made in the walls, especially on the faces exposed to the north or the east, auxiliary openings similar to those previously mentioned, and capable of being opened or closed at will by means of internal valves furnished with self-closing springs.

As the air thus introduced may be too cool at night, it is necessary that it should be directed from the lower part of the room toward the ceiling, and that its velocity at entrance should be about 2 feet a second, in order that it may be rapidly diminished before it arrives at the escape-openings.

The regulating-apparatus connected with the registers should be so arranged as to be exclusively under the control of those in charge of this service.

When any arrangement for ventilation on the exhaust-system has been carried out, it may easily be determined by direct experiments easily made in the main ventilating-chimney, or, if desired, in the separate flues, whether the prescribed amount of air is really drawn off, and what is the corresponding excess of temperature in the chimney over that of the external air; and if with this excess, which usually will not vary, as has been previously stated, much from 35° to 45°, the ventilation be found sufficient, it will then only be necessary to regulate the heat in the chimney so that its temperature will always exceed by the same amount that of the external air.

92. *Arrangements for ventilation in summer.*—When the main halls of the hospital are warmed at the same time by general heaters and by fire-places—of which latter the ventilating fire-places described in § 13 should be preferred, as they at the same time carry off foul air and introduce a considerable amount of fresh air properly warmed—openings for the admission of fresh air should be made in addition to those of the ventilating-chimney, and arranged, as has been described, for summer-ventilation.

Stairways, waiting-rooms, and other places giving access to the halls should be heated to a temperature which, especially for the latter, should be at least equal to that of the halls. In this way, their effect in producing draughts of air will be diminished. It would be well, then, to put up heaters in these places even when fire-places are used in the main rooms.

93. *Use of the heat given out by the lights.*—In hospitals lighted by gas, it will be well to assist the draught by means of the heat given out by the burners, which plan will have the double advantage of rendering the ventilation more energetic, and of removing the unhealthful products of combustion. This should especially be applied in the case of water-closets, which should have double doors opening from without inward in the direction of the draught.

The kitchens and the privies of hospitals should be removed from the hospital proper, and ventilated by a powerful current similar to those which will be described hereafter for such places.

94. *Dispositions to be made in case of crowding or epidemics.*—When the draught is produced by a circulation of warm water or steam, the energy

of which cannot be increased much beyond its normal rate, it will be advisable to place gas-burners in the main ventilating-chimney, to be lighted only when a temporary overcrowding or the fear of epidemics renders their use necessary.

The number of burners and their consumption of gas will be calculated on the approximate basis of 500 cubic feet of air removed to each cubic feet of gas burned.

This auxiliary means is not economical, and should only be employed in exceptional circumstances.

ASYLUMS.

95. Asylums, designed for the old, insane, or infirm, do not require, for salubrity, as much ventilation as hospitals.

A renewal of air at the rate of 1,000 cubic feet of air an hour for each individual during the day and 1,400 cubic feet at night will be sufficient. It will then only be necessary to adopt the plans and the dimensions which have been given in detail for hospitals.

For heating during the winter, if the rooms are not very large, ventilating fire-places should be used, which will also secure the renewal of air. But for spring, summer, and autumn, it will be necessary to have recourse, for the removal of foul air, to the use of a ventilating-chimney and the arrangements before mentioned.

CHURCHES.

96. The great size of churches, the constant opening of their doors, the extent of glazed windows—always imperfectly closed—the openings in the vaults for the suspension of lamps or draperies and for the passage of bell-ropes, seem in general to render unnecessary the adoption of special arrangements for the admission and the removal of air, and reduce for the winter the question to that of warming.

For the churches of large cities, frequented at many hours of the day, it seems economical to keep up an active fire, constantly, day and night. Either hot-air heaters, with chambers for the admission of cold air, or hot-water heaters, may be used. The first suit more particularly the small churches, where a single heater, placed about the middle of the building, will suffice. The second, which carry heat to great distances, and give, besides, a more equable temperature, should be preferred for large churches. They have, in addition, the advantage of being readily adapted to ventilate certain attached places, such as catechising-rooms, where the air is constantly vitiated by the presence of many children.

What is most necessary to warm in churches is the floor itself. For this purpose it would be well to make the hot-water pipes branch out under many parts of the floor, and limit the number of fresh-air openings. This arrangement is similar to that of which traces are found in Roman constructions.

The air to be warmed by the heaters is taken from outside. A sufficient number of pipes in the aisles and passages admit the air through numerous openings placed in the vertical faces of the walls, or in the bases of the columns, a little above the floor, and not at the floor-level, as is often wrongly done.

During the summer season, the interior of churches, strongly heated during the day by the action of the sun on the roof and through the large windows, is often uncomfortable to stay in, especially in the morning. It would be easy to avoid this trouble by arranging a number of windows to be opened at night, in order to admit the fresh air, and to be shut in the morning. The interior, thus cooled during the night, would be less warmed during the day.

These precautions, much neglected in France, where the heat of summer seldom proves unpleasant, are regularly carried out in Rome, where it lasts a long time. A rule of the custodians of St. Peter's requires that the windows of the upper galleries be opened every evening in summer and closed every morning.

What precedes only applies to ordinary churches; but in the case of chapels or subterranean churches, the interior height of which is very limited and which are often occupied by a large number of worshippers and fully lighted up, it becomes necessary to secure the renewal of air and the removal of the hot gases arising from the lights. The plans proposed in § 64 for night drawing-schools should then be adopted, producing a renewal of air at least five or six times an hour.

In churches where great ceremonies require the use of large canopies, preventing the circulation of the air, and in which a great number of candles occasion often an extraordinary elevation of temperature,* it is very important that the construction should allow of forming, in the upper or lateral portion, as many openings as possible in order to allow the external air to flow in with a velocity which will be less the greater the number of these openings and the more uniformly they are distributed. In this way will be avoided the at times unendurable currents of air produced by the doors and the elevation of temperature.

In winter, at the time of thaws after great cold, especially in the north, there is produced on the walls, and still more on the ceiling, a condensation of vapor, which often produces a sort of rain that affects the paintings. In such cases, it would be well to carry the warm air supplied by the heaters at about from 140° to 175° directly to the upper part of these edifices at the springing of the arches, in order to keep the vapor arising from the people in the lower portions of the church from condensing.

RAILROAD-STATIONS.

97. As an example of cases where it is proper to act contrary to the general rules given before, we will specify the methods to be adopted for

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*In a great funeral-ceremony at Notre-Dame, Paris, the heat was such that the wax-tapers began to melt.

railroad-stations, for markets, and for large buildings such as those for exhibitions.

These immense buildings, covered in most cases with glass roofs, which often leave only a very small space for the escape of the smoke and steam ot the locomotives and of the hot air in summer, sometimes become unendurable for the employés. One end of the building is almost entirely shut in by the gable-wall containing the main entrance; the other usually has an opening only high enough for the passage of the locomotive; the sides occupied on the ground-level by waiting-rooms, &c., and on the second and third floors by offices, do not allow the air to have access to the building, and in the hot season the temperature rises near the ground-level to 104°, 113° and even 122°, as has been observed at the stations of the Lyons, Eastern, and Strasburg railroads.

In order to remedy this state of things, it is necessary to raise the sky-lights on the roof, not only because they are too low, but because in winter they cool the smoke and partially condense the escape-steam of the engine, and thus interfere with its removal.

Instead of placing the sky-lights at the ridge of the roof, it would seem better to place them near the eaves, making them, as at present, equal to one-fourth or one-third the total surface.

The ventilating-opening should be formed by two vertical walls of sheet-iron about 10 feet high, leaving between them a passage extending the whole length of the roof, the breadth of which should be calculated so as to renew the air of the station at least twice or three times an hour, on the supposition that the heat of the sun in summer is sufficient to produce, in a sheet-iron chimney 10 feet high, a velocity of from 1½ to 2 feet a second.

To replace regularly the air removed without producing unpleasant currents at the end-openings of the station, it is necessary to increase the number of openings for admission of air, and place them as uniformly as possible throughout the extent of the station, and also to make large doorways in the two ends of the building. The total area of the fresh-air openings should be such that, with a velocity of at most 16 to 20 inches a second, a volume of air may enter into the station equal to twice or three times its cubical capacity.

98. *Sprinkling of roofs.*—In addition to the preceding arrangements, proper for all seasons, it would be well, in hot weather, to keep up a constant sprinkling of the roof, commencing at seven or eight o'clock in the morning and lasting till five o'clock in the evening, using about 4½ cubic feet of water an hour to every 100 square feet of roof-surface.

This sprinkling, which will be sufficient to prevent the heating of the roof by the action of the solar rays, added to the continued aeration, will maintain the temperature within convenient limits during the hot season.

99. *Example.*—The Orleans station is 348 feet long, 92 feet wide, 26 feet high at the springing-line, and 44 feet to the ridge. Its cubical content is about 1,130,000 cubic feet.

To renew the air three times an hour, it should carry off $\frac{3 \times 1130000}{3600}$ =942 cubic feet a second. The velocity which the solar heat may give to the escaping air being estimated at but 1⅝ feet a second, the sectional area of the ventilating-space should be 574 square feet; and if the ventilating-passage is carried the whole length of the roof, which is 328 feet, it would suffice to make it 1 foot 9 inches wide. But as the part where there is most smoke and steam is usually near the end at which the trains leave, instead of making the ventilating-opening extend the whole length of the station, it would be better to give it greater breadth and less length, still retaining the same sectional area.

COURTS AND COVERED MARKETS.

100. Similar arrangements should be adopted in the case of courts and for all covered markets.

In the latter, where blinds are usually placed in the windows, the introduction of air is easily provided for, and it is particularly the removal of foul air that requires attention.

GLASS ROOFS AND CEILINGS.

101. *Influence of glazed roofs and ceilings during the winter.*—If in the summer season the glazed roofs of stations and covered courts present the inconvenience of producing a heating effect, which it is necessary to overcome, in winter they have the contrary defect, which often leads to very disagreeable results.

The conductibility of thin glass then leads to a considerable cooling of the interior layers of air in contact with the glass; this air, becoming denser than that below, descends, and is constantly replaced by more, which is likewise cooled, and by this continued movement the rooms thus covered become very difficult to warm.

To these troubles is added that of the motion of the cold air, which naturally flows toward the chimneys, or the discharge-openings, if there are any, so that the occupants feel a descending current of cold air, the more unpleasant the nearer they are to the chimney or the discharge-openings.

If the glass roof is simple, and has, as is almost inevitably the case, joints, through which the external air—much colder than that in contact with the internal surface—penetrates into the room, the effects which have been mentioned become more sensible and disagreeable. There is also the danger that water will enter during rain-storms.

It is, then, necessary in occupied buildings, when similar plans are adopted for lighting, to place under the roof a glass ceiling with as few joints as possible, and in the loft thus formed and limited above and below, to provide heating arrangements which will prevent the cooling of the ceiling, and thus to avoid the cold-air currents which have just been referred to.

102. *Observations at Château de Ferrières.*—The most striking example of these effects which I have had occasion to observe is presented by the great reception-hall of the Château de Ferrières, and it has furnished me with some facts which enable me to determine the amount of heat which such glass roofs may transmit, and, consequently, to determine approximately the methods of heating to be employed to prevent this cooling.

The main reception-room of the Château de Ferrières, called the Hall, is 75 feet long and 40 feet wide, or 3,000 square feet in area.

It is completely surrounded by other reception-rooms, corridors, vestibules, &c. By means of heaters, all these are comfortably warmed, as well as the reception-room, which has no side-windows, but is lighted by a glass ceiling with a surface of 1,635 square feet, covered by a glass roof in seven sections, having together 2,459 square feet of cooling surface.

A large fire-place, in the form of a monument, placed on one of the long sides of the room, completes its system of heating.

When in winter the space between the glass roof and ceiling is not warmed during the day, the effects previously mentioned become the most unpleasant. The considerable draught of air produced by the fire-place draws to it the air cooled by contact with the ceiling; and the vicinity of this fire-place, to which persons are naturally drawn by a bright fire, becomes unendurable.

At night, the room is lighted up by 1,000 gas-burners above the ceiling, which consume 3,500 cubic feet of gas an hour; there being then about one burner to every three square feet of floor-surface in the room. The heat given out by this abundant combustion more than suffices to prevent the cooling of the air of the room and the unpleasant effects which would result from it.

To obtain at least to a certain degree the same result during the day, it has been found necessary to keep up coke-fires in four cast-iron stoves, placed in the roof-space, in order to maintain there a temperature higher than that of the room.

Observations made on the consumption of coke during the day and of gas at night, as well as upon the internal and external temperatures, enable us to calculate at least approximately the amount of heat required in the space between the glass roof and ceiling in order to prevent the unpleasant cooling effect.

For this purpose, calling—

C the number of units of heat which can pass in an hour through a pane of glass having the surface S;

T the temperature of the air on the warmer side;

T′ that of the air on the colder side;

K a constant co-efficient, representing the number of units of heat to a square foot of glass surface, and to a degree of difference of temperature between the two faces:

The amount of heat passing in an hour through a glass ceiling or roof will be given by the formula—

$$C = K S (T - T')$$

Engineers only admit for the co-efficient K the value $K = 1$, while the data obtained at Ferrières seem to show that for a double glass covering—that is to say, a glass roof and a glass ceiling—it should have the value $K = 3$, and for a single covering $K = 4$, especially as in the latter case cold air might penetrate into the interior through the joints of the glass.

According to these values, allowing that the developed surface S' of the roof is one and a half times that of the glass ceiling S, the amount of coal to be burned in the coldest weather may be calculated as follows:

Let—

$S = 1{,}000$ square feet;
$S' = 1{,}500$ square feet;
The temperature of the external air be 14°;
The temperature to be maintained within the roof be 113°;
The temperature of the room, 59°:

The amount of heat passing off through the glass roof will be—

$C = 3 \times 1500\,(113 - 14) =$ .... 445,500 units.

The amount of heat passing off through the glass ceiling will be—

$C = 3 \times 1000\,(113 - 59) =$ .... 162,000 units.

The amount of heat to be developed within the double roof = ... 607,500 units.

Admitting that the coke-stoves employed utilize, as is almost always the case under similar circumstances, 90 per cent. of the heat given out by the fuel, and that a pound of coke produces 12,600 units of heat, it is necessary to burn every hour $\frac{607500}{.90 \times 12600} = 53.57$ pounds of coke an hour to prevent, under these almost extreme conditions of cold in Paris, the glass from cooling the room beyond 59°. At evening-receptions, the lighting-up of the room requiring a burner consuming 3½ cubic feet of gas an hour to every three square feet of floor-area, the heat produced will always be more than sufficient to prevent the cooling of the interior.

The preceding figures show why most makers of heating-apparatus who have undertaken to warm halls or courts covered by sky-lights have only very imperfectly succeeded.

DWELLING-HOUSES.

103. Among the appendages of dwelling-houses which most often give out disagreeable smells should be placed, in the first rank, yards, kitchens, and privies. In consequence of the draught exerted by the chimneys of rooms near these places, it often happens that at certain times more or less infectious air is drawn into the apartments.

To avoid this serious trouble, it is necessary, by means of proper arrangements, which should also be simple, to produce a regular and almost constant motion of air from the apartments or the halls toward these places, discharging from them to the exterior. This may be accomplished in several ways.

104. *Court-yards of dwelling-houses.*—Apartment-houses, especially in Paris, very often contain little yards, belonging to the stores on the ground-floor, which seriously affect the healthfulness of the upper stories. Provision-stores, restaurants, dye-houses, drug-stores, &c., give rise to disagreeable or injurious smells, which rise and annoy the occupants of the house and injure the property.

These disagreeable effects may easily be overcome in the following way: The yard should be covered, in whole or in part, with a glass roof, forming a single inclined plane between the ground-floor and the second story. In an angle, and at the upper part of this roof, should be placed a chimney, extending above the upper cornice, the section of which should be calculated so that with a velocity of about three feet a second the air of the court-yard will be renewed once, or, better, twice an hour.

At the lower part of this chimney should be placed a gas-burner, consuming only 3½ cubic feet an hour. The velocity being small and the chimney high, about 1,800 or 2,000 cubic feet of air may be carried off in an hour by this chimney to every cubic foot of gas burned, and thus a constant purification of the yards be secured.

When local arrangements favor, it will only be necessary, in order to keep up the draught, to carry a smoke-pipe up the chimney, or to start a fire in a coke-stove placed in it.

105. *Kitchens.*—When ranges with hot-air passages, such as are now in general use, are employed, it will be easy when they are put up to place hot-water pipes around the grate, and carry them a certain distance up the chimney and back to the range, as in the boilers of hot-water heating-apparatus, which would secure a sufficient draught.

106. *Use of gas-burners for the ventilation of kitchens*—In kitchens lighted by gas, when the ranges are already put up in the usual way, lighting one or two gas-burners at the bottom of the chimney, to be kept burning only while cooking is going on, would in most cases suffice to produce a draught sufficient to carry off all smell.

Example.—The kitchen for a single flat in Paris is considered quite large if 10 feet long, 13 feet wide, and 11½ feet high; that is, with a content of 1,490 cubic feet.

It follows from direct experiment that, with the aid of a single gas-burner, consuming 1½ feet an hour, and kept burning only while the meals are being prepared, that is to say, at most six hours a day, there may be produced every hour, with sheet-iron ventilating-pipes 9½ inches in diameter, and

	52	39	33	26 feet high,
the renewal of	1,780	1,475	1,407	1,257 cubic feet,

which, added to the natural ventilation produced by the kitchen fire, will fully suffice to change the air of such a kitchen more than once an hour.

The expense for a whole year for one small gas-burner, consuming 1½ feet of gas an hour, and burning six hours a day, would be 8½ cubic feet a day, or 3,100 cubic feet a year, which, at the rate of $1.70 a thousand feet, would cost $5.27, a very moderate expenditure for getting rid of a nauseous smell, which would otherwise be experienced twice a day.

It may be added that the preceding results relate to metal pipes placed on the outside and exposed to cooling, while, in general, similar ventilating-pipes may be, and ought to be, made of earthen ware, and placed in the thickness of the walls or in the interior of buildings, which, exposing them less to cooling, would increase the effect obtained. In the case of large kitchens with wide fire-places, when the ranges are kept very hot, and are used almost all the time, it would be more economical to place a coal-grate in the lower part of the chimney, at about the top of the fire-place, and this would also be the most simple and direct method for country-houses.

107. *Use of the lost heat from kitchen-ranges for ventilating and for heating baths.*—Besides the advantage of securing a change of air and the removal of bad odors from the kitchen, the hot-water pipes mentioned in § 105 serve to supply baths, which may be established with success, as mentioned in § 81 in barracks, as well as in those establishments where provisions are cooked for the poor, to be distributed to them gratuitously or sold to them at a low price. The addition of hot-water baths to these useful establishments might thus be made at very little expense.

An arrangement of this kind is adopted with success in the new lying-in house established by the administration of public assistance, rue du Faubourg St. Jacques, to utilize the lost heat from the stoves used for making plasters.

108. The baths may be heated also by means of ordinary hot-air kitchen-ranges without recourse to the use of hot-water circulation, or, what is better, by combining the two means of utilizing the heat lost from the range during the time the meals are being prepared.

109. *Privies.*—The necessary arrangements to be made in order to prevent the infection which these attachments to buildings often produce vary with the mode of construction adopted and the nature of the building.

The regulations for the construction of privy-wells are as follows: The down-pipes should dip at their lower end into the contents of the well, or better into a fixed or movable copper basin, into which it is well when it can be done to force water from time to time in order to wash it.

It follows from these arrangements that the only gases which can ascend in these pipes arise from their internal surface or at the bottom of the pipes, and will not be very abundant, (Fig. 30.)

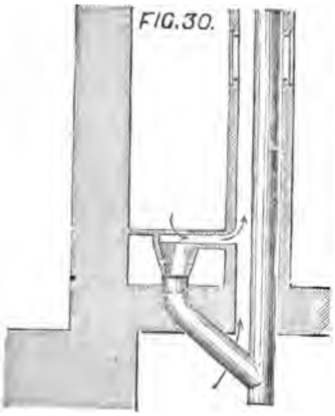


FIG. 30.

To prevent the gases from spreading to the interior of the rooms, water-closets called English closets are usually employed within dwellings. In less particular houses and in public establishments, there is simply placed under the opening a basin called Roger Mothe's apparatus, which tips and empties itself by the weight of the contents alone, and then returns and closes the opening.

These convenient means are not always sufficient to prevent the introduction of bad smells on account of small cracks in the joints of the apparatus.

In all cases it is better to keep the seat 1½ or 2 inches above the upper edge of the bowl, letting the front and the two sides reach to the seat and to connect this space with a ventilating-pipe extending above the roof.

If this pipe can be placed near a source of regular heat, such as the kitchen-flue, or if hot-water pipes can be carried into it, as in the case of mansions heated by hot water, it would be easy to obtain a sufficiently powerful draught in this pipe.

But if this method is not available, as often is the case in small dwellings, the same effect may be secured by placing in the pipe a small gas-burner, burning at most 1 or 1½ cubic feet an hour, and which, by the aid of a transom, will illuminate the closet at the same time that it purifies it. A common lamp might even be made use of, burning ½ or ¾ ounce of oil an hour, (about $\frac{1}{36}$ to $\frac{1}{24}$ of a pint.)

The ventilating-pipe should be about from 46 to 62 square inches in area, and the small burner, burning 1½ cubic feet an hour, would, in most cases, secure the renewal of 1,000 cubic feet of air an hour, which would suffice not only to expel all the gases coming from the seat and its descending-pipe, but even to renew the air of the room several times an hour by drawing in that of the surrounding corridors and also prevent the infection of the interior of the house.

110. *Example.—Office of the Northern Railroad Company*, (Fig. 31.)—If, instead of English water-closets, only open seats are used, or even those called Turkish seats, similar arrangements would produce the same results.

Fig. 31 shows the plan adopted with success in the office of the Northern Railway Company, where there are in the five stories twenty-seven water-closets. The down-pipes serve for all the pairs of seats in each story, and are only three in number. They are 9 inches in diameter, and terminate in the movable copper water-basins, which form siphon-traps and prevent the rising of the gas from the well.

FIG.31.

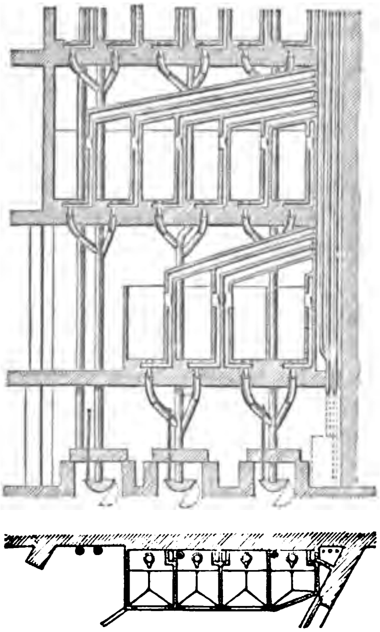
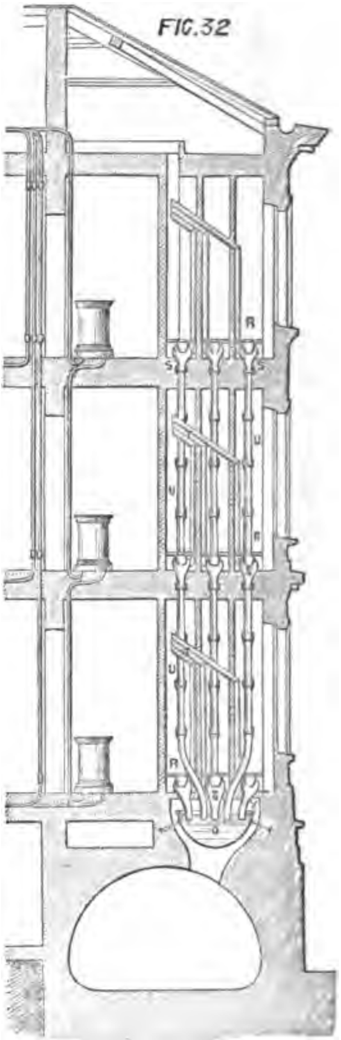


FIG.32



All the ventilating-pipes from the seats are 4 inches by 16 inches inside. They terminate in a large vertical collecting-pipe, about 10 square feet in sectional area, serving as a ventilating-chimney, in which are placed vertical hot-water pipes, which in winter produce a general draught. In summer, when the heating is interrupted, the draught is produced by gas-burners kept burning in each closet.

Ventilation by means of hot-water circulation can evidently be kept up in summer by means of a separate fire for this special purpose, which would be more economical than the use of gas.

The result of experiments made in February, 1863, was that the amount of air removed for each seat under the action of the draught, produced simply by an excess of 7° to 13° of temperature in the chimney over that of the external air, was more than 2,200 cubic feet an hour.

Although much greater than is generally necessary, this amount would not seem excessive in similar cases where, in addition to the seats, urinals, often imperfectly rinsed, are used.

111. *Arrangement adopted at Lariboisière Hospital*, (Fig. 32.)—In this establishment, the closets on each floor contain three seats, with bowls,

R, of enameled cast iron, which empty into another bowl, S, forming the top of a down-pipe, U, of which there is one for each seat, but which, by a simple arrangement, might have been more economically made common to the three floors. These down-pipes carry the contents to a large hemispherical basin, O, of cast iron, always filled with water, in which their ends dip so as to prevent the gas from the well at the bottom from rising through the pipes. The contents run off from the basin O through the space X in the well, which is closed air-tight, and which, according to the regulations, should be provided with a pipe for the escape of gas to the top of the building.

It follows from this arrangement that the only gases which can rise to the top of the down-pipes in the closets are those which are formed in the pipes. To prevent them from entering into the closets, and at the same time to renew the air in the latter, M. L. Duvoir has connected each of the under-bowls S with a pipe, T, leading to a ventilating-chimney common to all the closets.

The draught exerted by this pipe V, increased by the use of hot-water pipes or by other means, not only removes the gas developed in the down-pipe, but it carries off from the closets, through the hole in the seat, an amount of air equal to 1,200 cubic feet or more an hour to each seat.

Arrangements similar to the preceding have been applied with success in privies with Turkish seats in building *b* of the Vincennes Hospital.

SINKS.

112. When sinks, intended to receive kitchen-slops, give out a bad smell in spite of the precautionary measures prescribed by the sewer-regulations, or when these regulations are not or cannot be observed, this unpleasantness may be removed by means similar to those just mentioned.

DINING-ROOMS.

113. In these rooms, where the steam from the dishes and the heat from numerous lights, added to that produced by the people present, cause a temperature often insupportable, it is easy to apply the rules previously given.

It will usually suffice if the air be renewed four or five times an hour, producing the draught near the floor, and making use, as will often be very easy, of the heat from the wall-brackets to give it the required force.

If the room is brilliantly lighted by many chandeliers placed over the tables, an escape should be provided for the hot gases arising from the combustion by openings in or near the ceiling.

The openings for the admission of fresh air should be placed below the former, but removed as far as possible from the people.

It will then be found, as in the case of night drawing-schools, that the general rules will have to be modified.

As examples, chosen among those which apparently offer the greatest difficulties, I select the dining-rooms of the Hôtel de Ville, Paris.

114. *State dining-room.*—This immense room has the following dimensions: length, 156 feet; breadth, 34 feet; height, 38 feet; cubical content, 200,000 cubic feet; floor-surface, 5,300 square feet. There are usually at dinner there 180 persons at one table 152 feet long by 13 feet wide, which gives a contour of $2 \times (152 + 13) = 330$ feet, and allows each guest but 1.8 feet of space.

At dinners, the number of waiters cannot be less than 60. There are therefore 240 persons in the room.

The cubical space to each person is then—

$$\frac{200000}{240} = 833 \text{ cubic feet.}$$

The amount of floor-surface to each person is—

$$\frac{5300}{240} = 22 \text{ square feet.}$$

Under these conditions, it is illuminated by—

26 chandeliers, each containing 100 candles	2,600
Table-candelabra of 6 or 7 candles each	592
Total number of candles	3,192

At the dinner given by the city to the Emperor on the occasion of his marriage, there were 420 persons at table. The number of waiters was at least 100; the cubical space for each person was then—

$$\frac{200000}{520} = 384 \text{ cubic feet,}$$

and the floor-surface to each person—

$$\frac{5300}{520} = 10 \text{ square feet.}$$

The room was lighted, on this occasion, by

26 chandeliers of 100 candles each	2,600
Table-candelabra	592
Total	3,192

Admitting that each candle develops 476 units of heat, the same as a person, the total number of units of heat developed in an hour, on that occasion, would be—

$$(520 + 3192) \times 476 = 1{,}766{,}912 \text{ units.}$$

Supposing that air, at a temperature of 59°, had been admitted at a height of 20 or 26 feet, and that this air, after its temperature had been raised to 95°, had escaped through openings in the ceiling, every cubic foot of air introduced would have carried off—

$$.0766 \times 36 \times .237 = .6536 \text{ unit.}$$

It would then have been necessary to admit into and withdraw from the room every hour the enormous amount of—

$$\frac{1766912}{.6536} = 2,703,000 \text{ cubic feet of air,}$$

or 751 cubic feet a second, which corresponds to a complete renewal of the air of the room effected—

$$\frac{2703000}{200000} = 13.52 \text{ times an hour.}$$

By means of chimneys extending to the roof, a velocity of discharge equal to at least 7 feet a second could have been obtained, and their sectional area and that of the openings into them would have to be 114 square feet. Supposing five of the latter to be placed in the ceiling, each would require to be 23 square feet in area.

However great the amount of air to be removed and the areas of flues may seem, there need be no serious difficulty in obtaining them.

115. *Throne-room.*—This room has the following dimensions: length, 94 feet; breadth, 36 feet; height, 26 feet; cubical capacity, 88,000 cubic feet; floor-surface, 3,380 square feet. It accommodates 95 guests at a table 77 feet long by 13 feet wide, having, therefore, a circumference of 180 feet, which gives each guest but 1.9 feet of space.

The number of servants is about 25. There are then 120 persons in the room.

The cubical space to each person is—

$$\frac{88000}{120} = 733 \text{ cubic feet.}$$

The floor-surface to each person is—

$$\frac{3380}{120} = 28 \text{ square feet.}$$

Under these circumstances, it is lighted up by—

12 chandeliers of 96 candles	1,152
4 candelabra of 25 candles	100
On the table	370
Total	1,622

or, 17 candles to a guest.

Allowing, as before, that a candle gives out 476 units of heat an hour, the same as a person, the total number of units of heat given out an hour would be—

$$(120+1622) \times 476 = 829,192 \text{ units.}$$

Supposing that the air had been introduced at a height of 20 feet, and at a temperature of 59°, and that this air, after having become heated to 95°, had escaped through openings in the ceiling, every cubic foot of air introduced would have carried away, as in the preceding case, .6536 unit.

It would then be necessary to admit into, and discharge from, the room every hour the amount of—

$$\frac{829192}{.6536}=1,268,000 \text{ cubic feet,}$$

or 352 cubic feet a second, which corresponds to a complete renewal of the air of the room effected 14.27 times an hour. If the velocity of discharge reaches 6½ feet a second, the total sectional area of the openings should be 54 square feet.

The amount, 1,268,000 cubic feet, is about that which can easily be withdrawn from the lecture-rooms of the Conservatory, and introduced there at a mean height of less than 20 feet without inconvenience to the audience.

116. *Dining-room.*—This room has the following dimensions: length, 49 feet; breadth, 23 feet; height, 25 feet; cubical capacity, 28,000 cubic feet; floor-surface, 1,120 square feet.

It accommodates 54 guests at a table 42 feet long by 10 feet wide, having therefore a circumference of 104 feet, and giving to each guest but 2 feet of table-space.

The number of servants is about 14. There are then 68 persons in the room.

The cubical space for each person is—

$$\frac{28000}{68}=410 \text{ cubic feet.}$$

The floor-surface to each person is—

$$\frac{1120}{68}=16 \text{ square feet.}$$

It is lit up by—

1 chandelier	60 candles,
14 chandeliers of 20 candles each	280 candles,
Portable candelabras	170 candles,
Total	510 candles,

or 9.44 candles to a guest.

Admitting the same bases of calculation as before, the total number of units of heat developed in an hour by the people and the candles will be

$$(68+510)\times 476=275,128 \text{ units,}$$

and the amount of air to be admitted and withdrawn every hour would be—

$$\frac{275128}{.6536}=421,000 \text{ cubic feet,}$$

or 117 cubic feet a second, which corresponds to a complete renewal of the air of the room effected 15.23 times an hour.

The amount, 421,000 cubic feet, is less than that which is constantly admitted into and withdrawn from the small lecture-room at the Conservatory.

Under the arrangements at present in use, it is not uncommon to find at the close of a meal a temperature of 86° without any change of air, which is very unpleasant, and the supposition that it will be 95° near the ceiling is probably below the truth.

The three preceding examples present extreme difficulties ; and it is besides evident that if the proportions referred to be adopted, it would be necessary to reserve means of regulating and of moderating, according to circumstances, the amounts of air to be admitted and carried off. For the winter season, the latter should be taken from places near the rooms where a suitable temperature can be maintained.

RECEPTION-ROOMS.

117. What has already been said in regard to dining-rooms applies equally to large reception-rooms, where many lights serve to a great extent to heat and vitiate the air.

There, as in evening drawing-schools, it will not be sufficient merely to produce a change of air proportioned to the number of persons present; it is necessary at the same time to carry off the hot gases of combustion through the ceiling under the influence of the draught which they produce, and to establish at the same time if possible an outward draught near the floor, which will draw to it a part of the fresh air. The fresh air should be introduced at a considerable height, and as far as possible from the people in the room.

In such cases, it will be advisable to secure the complete renewal of the air six or eight times an hour.

Observations made at the school in the Rue des Petits-Hôtels having shown that, with an external temperature of 50° and an internal temperature of 79°, there will be produced from free openings, disconnected from any chimney, a velocity of about 3 feet a second, the surfaces of the openings to be made above may be calculated by assuming that 75 per cent. of the amount of air to be removed escapes through these openings; and that the balance, or 25 per cent., will be drawn off at the bottom, with a velocity also equal to at least 3 feet a second.

118. *Application to the Hall of Marshals in the Tuileries.*—This reception-room is 63 feet long, 53 feet wide, having therefore 3,340 square feet of floor-surface, and 48 feet in mean height, the cubic content being about 160,000 cubic feet. It accommodates at most six hundred people at balls, or about one person to every 5 square feet.

It is lit up on reception-days by 548 candles and by 166 lamps, (equivalent to 498 candles,) which would develop together about 500,000 units of heat an hour.*

The illumination corresponds then to—

$$\frac{1046}{600} = 1.74 \text{ candles to an individual.}$$

If it is desired that the air be renewed in this hall six times, it will be necessary to admit and discharge—

$$6 \times 160{,}000 = 960{,}000 \text{ cubic feet an hour,}$$

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* *Études sur la ventilation*, 2e vol., pp. 301–302.

of which $.75 \times 960,000 = 720,000$ cubic feet an hour, or 200 cubic feet a second, will be carried off at the ceiling, and $.25 \times 960,000 = 240,000$ cubic feet an hour, or 67 cubic feet a second, by the openings near the floor. As the velocity of discharge near the ceiling may be as high as 3 feet a second, the openings to be made there—as far as possible directly above the main chandelier—should have—

$$\frac{200}{3} = 67 \text{ square feet of clear passageway,}$$

deduction being made for solid parts; and the velocity of draught near the floor being also 3 feet a second, the corresponding openings should have a clear area of—

$$\frac{67}{3} = 22 \text{ square feet.}$$

The grating in use has an area of but 116 square feet of total surface, including solid portions, and scarcely presents 43 square feet of clear passage.

Above the openings in the ceiling should be placed external ventilators, having together the same clear area, which will increase the velocity of discharge.

In regard to the ventilating openings at the floor-level, they may easily be made around the contour of the rooms under the steps on which the seats are placed; and their pipes should be carried in the piers of the vaults of the lower vestibule to the cellar, where they should join the collecting passages terminating in a general ventilating-chimney, at the bottom of which a coal fire or a number of gas-burners should be kept burning.

The dimensions of these pipes should be calculated by the general rules previously given. If there are serious difficulties in the way of producing this down-draught, an up-draught may be used, produced by the aid of gas-burners placed in vertical flues made in the thickness of the walls.

119. *Introduction of air.*—But it is not sufficient merely to secure the discharge of the foul air; it is necessary to provide for the admission of an equal amount of fresh air at a proper temperature.

This air, which in winter should be warmed to a temperature of about 68°, may be admitted through an interjoist in the balcony, which is 20 feet above the floor. It should flow horizontally below the chandeliers, above and away from the occupants, and its horizontal velocity of admission may, without inconvenience, be 3 feet a second. Its volume being 954,000 cubic feet an hour, or 265 cubic feet a second, the total sectional area of the interjoist and of the conducting passages should be 81 square feet.

The length around the inner edge of the balcony being about 200 feet, it will suffice to give the openings—

$$\frac{81}{200} = .4 \text{ foot of clear height,}$$

but on account of the ornaments which break up the passage it will be necessary to make them 10 inches either in height or in developed profile.

These arrangements will insure the renewal of 954,000 cubic feet of air an hour, or 1,590 cubic feet to each person, if there are 600 present, sufficient in all seasons to secure the healthful condition of the room and to moderate its temperature; but it is not necessary that they be isolated and confined to one of the reception-rooms of the palace. It will be equally necessary to adopt similar arrangements for the two adjoining rooms, which often contain many persons, and also for the large gallery, frequently used as a ball room. It may not be unnecessary to add that for evening parties the two large fire-places which are in the grand gallery may, by means of gas-burners placed within them, serve as ventilating-chimneys; and if there is any difficulty in cutting in the side-walls descending flues leading to the basement, ascending flues may be made, separate, or communicating with a single ventilator placed in the roof over each room.

The fresh air should enter above the cornice, and in a horizontal direction.

Each of the principal saloons in the palace should thus have its own ventilators provided with regulating-valves; they should be independent of the others, and this will prevent the unpleasant currents which would otherwise arise as the guests take their departure.

HALLS OF ASSEMBLY AND LECTURE-ROOMS.

120. These places of temporary resort, where there is often more than one person to every square foot of floor-surface, should be ventilated at the rate of 1,000 cubic feet of air an hour to each person.

The arrangements which I have adopted for the main lecture-hall of the Conservatory of Arts and Trades, and of which the satisfactory results have been seen every day for five years, appear to me worthy of imitation.

The foul air is drawn off through openings in the risers behind the feet of the auditors, and their total clear area for the passage of the air —deduction being made for the solid portions of the grating, if there are any—should be calculated so that the air will only attain a velocity of 28 or 30 inches a second. This surface also should be distributed as uniformly as possible among the steps.

The basement under the lecture-room, kept as clear as possible, should communicate with a ventilating-gallery, placed underground or at the ground-floor level if possible, the sectional area of which should be calculated so that the velocity of the air shall not be greater than 4 feet a second.

This gallery should terminate in a ventilating-chimney, the mean section of which should be determined on the condition that the velocity of the air shall reach 5 or 7 feet a second in order to secure the permanence of the current.

At the foot of this chimney, a grate, separated from the walls and placed about 3 feet above the ground, should contain a coal-fire, which will give to the draught the necessary strength. Experiments show that with proportions about equal to those that have been mentioned, 140,000 to 160,000 cubic feet of air an hour can be carried off from a well-filled lecture-room to every pound of coal burned. On the preceding data, the number of pounds of coal to be burned may be calculated from the number of persons in attendance, allowing to each 1,000 cubic feet of air an hour, and the surface of the grate may be determined on the condition that each square foot is to consume 4 pounds an hour, which corresponds to a slow fire.

Doors and valves should be placed in this gallery to check the motion of the air as required.

If in the lecture-room substances that give off bad smells are produced, ventilating-pipes should be arranged under the furnaces, or under the table, which should be 2½ or 3 square feet in sectional area, and prolonged, if desired, directly to the chimney instead of terminating in the gallery. The openings of these pipes in the furnace or in the table should be closed whenever it is not necessary to use them.

121. *Admission of fresh air.*—Generally it will be well, when the construction permits, to make the air flow in through the roof over the lecture-room, which should in that case be close and ceiled, or in an inter-joist, whence it will descend into the room through openings uniformly spread over the surface of the ceiling.

When this arrangement can be adopted, the clear surface of the openings should be calculated on the condition that the air should pass through them with a velocity of about 20 inches a second.

In the main lecture-room of the Conservatory, where the amount of air admitted rarely exceeds 636,000 cubic feet an hour, or 177 cubic feet a second, this condition would require a clear area for the fresh-air openings of 108 square feet. They actually have an area of 129 square feet.

If it becomes necessary to admit the fresh air through one or more of the walls of the room, opposite walls should be preferred, and the openings should be placed as far as possible from the audience, fitting guides to them to force the air to follow the flat or curved surface of the ceiling, so that its entering velocity, which may then be as great as 40 inches a second, may be gradually reduced before it reaches the audience. The air brought in should have in winter a temperature lower by 4 degrees than that which is to be maintained in the room, which should be about 68°.

For this purpose, the warm air from the heating-apparatus should be mixed in a separate chamber with the cold air taken from outside through a convenient opening. The action of the draught will serve to draw in this cold air, which should be made to flow into the mixing-chamber above the warm air.

Valves should be arranged to regulate the amounts of hot and cold air so as to give a proper temperature to the mixture.

When the lecture-room is not occupied, it will be well to close all the communications with the ventilating-chimney, the mixing-chamber, and the fresh-air openings, in order to avoid reversed draughts which would cool the interior.

The intermittent use and heating of lecture-rooms causes a much greater expense for fuel than if they were constantly occupied.

These places also being only ventilated when they are in use, it is well to reserve means of warming through special openings different from those which are used in connection with ventilation, the openings to be afterward closed.

The mean results for heating and ventilating lecture-rooms arranged similarly to those in the conservatory will be as follows:

Consumption of coal in 12 hours.	For heating—to 1,000 cubic feet content	2–2½ lbs.
	For ventilation—to 1,000 cubic feet of air renewed	¾–1 lb.

Large reception-rooms, such as those of legislative halls, should be warmed and ventilated upon the same principles.

In all cases, it should be remembered that staircases, vestibules, &c., which give access to these places with strong ventilating-draughts, should be warmed without being ventilated, and kept at a temperature a little above that of the main room, so that the occasional opening of doors will only admit warm air, which would not be unpleasant.

Experiment has shown at the Conservatory that, when these places are thus heated and kept closed, they form a sort of air-lock, and the velocity with which the air enters through the doors, which being opened put them in communication with the interior of the lecture-room, is barely one foot a second, and consequently almost insensible, especially if the temperature of the air is at least equal to that in the main room.

THEATERS.

122. A theater is composed of three principal parts—

1. The stage and its accessories.
2. The auditorium, waiting-rooms, and dependencies.
3. The vestibules, staircases, and business-offices.

The stage, the flies, and the corridors which lead to the dressing-rooms and green room should be kept at a temperature of 64° to 68° in winter. Generally, the latter places will not require to be ventilated, as they contain but a small number of people, occupying a large space. Still, as the green-room and the rooms in which the chorus rehearses often contain a large number of artists, it may be necessary in certain cases to ventilate them. The upper portions of the stage are often raised to a high temperature on account of the heat produced by the lights, by the fire in spectacles, &c., which requires that special precautions be taken to air them and to remove the hot gases.

The auditorium and the waiting-rooms are the parts in which it is especially desirable to maintain salubrity, change of air, and a moderate temperature. The amount of air to be changed an hour to each spectator should be 1,400 cubic feet, and it is well to reserve means of increasing it to 2,100 cubic feet during the summer.

The heating may be effected either by means of hot-air heaters with sufficiently large mixing-chambers, as has been previously mentioned, or by hot-water apparatus, of which the first cost need not be greater than the preceding, while it will be very easy to regulate.

123. *Air-supply.*—The fresh air should be taken, if possible, from the neighboring gardens, far from dwelling-houses, or from court-yards, or by special chimneys, drawing it from the top of the edifice. Care should be taken that these chimneys should be as far as possible from the ventilating-chimneys, and that their tops be not as high as the ventilating chimneys, in order that they may not reverse the draught.

If fresh air be introduced by subterranean passages, the walls, the vaults, and the floor of these passages should be made of hydraulic masonry, perfectly tight, and nothing should be done to them by the custodians of the building, except to examine their state of cleanliness.

124. *Admission of air.*—The air should be carried into the auditorium:

1. By interjoists, formed between the floor of one gallery and the ceiling of that below; the air should issue horizontally from the whole circumference of the interjoists, which should be at least 5 or 6 inches in clear height.

It may be assumed that the horizontal velocity with which it flows out will be 3 feet a second; but it is necessary to take care that the openings through the gratings which terminate the interjoist-spaces have at least a surface corresponding to this velocity, and that none of these openings be placed horizontally above the spectators of the lower tier of seats.

2. By openings arranged at the height of about 10 feet in the walls separating the stage from the auditorium; and there may also be formed there a chamber for mixing the warm air from the heaters with the cold air from outdoors.

3. By auxiliary pipes, intended especially for summer-ventilation, arranged, if possible, under the floors of the corridors of each gallery. They should take air from outdoors, and their section should be calculated, so that the velocity of passage shall not exceed 2 feet or 28 inches a second. All these pipes should be supplied with valves to close them when required in cold weather.

125. *Necessary precautions.*—Ventilation, by drawing out the foul air, necessarily causing the entrance of fresh air, it is necessary to see that the opening of doors does not occasion unpleasant currents. For this purpose, corridors, passage-ways, and staircases should be heated in

winter to a temperature of about 68°. The doors of adjoining boxes being usually contiguous, it will be well to place a hot-air opening in the corridors before each pair of doors, so that during the momentary opening of one of these doors warm air may enter into the corresponding box. The same plan may be carried out by each door in the passage-way; but it is necessary that these hot-air openings be placed in vertical planes, and not at the floor-level. The passage-ways should have two doors opening outward and inward, and between them should be a hot-air opening.

126. *Removal of foul air.*—This air should be drawn out of the room by ventilating-openings at the back of the boxes or galleries, or in the risers of the amphitheater. The clear surface of these openings should be calculated on the condition that the air shall enter with a velocity of 28 or 30 inches a second.

Each box or each pair of adjoining boxes of the same tier should have a special ventilating-pipe. The section of these pipes should be calculated on the condition that the air drawn out should have a velocity of 3 feet a second. For the first, second, and third galleries, these pipes should be carried to the ventilator above the chandelier.

For the parquet, the orchestra, and the lower boxes, and, if possible, for the first gallery, the foul-air pipes should descend. In the parquet and the orchestra, gratings arranged around the whole lower circumference of the partitions, together with other openings placed on top or on the sides of pipes carried along by the feet of the seats, will serve to direct the foul air in an interjoist placed under the floor. This interjoist, made high enough to be cleaned, should be divided in large theaters into two parts by a longitudinal division in the mean plane of the edifice.

Each of these parts should communicate with a separate ventilating-chimney, of which the opening should be either in the basement or at the height of the floor of the passage-ways in the parquet.

In no case should the ventilating-openings be placed at the floor-level, as has nevertheless been done at the Lyric Theater.

The foul air drawn off from the lower boxes and the first gallery should likewise be carried underneath by means of special pipes, afterward united in collecting-pipes terminating at the base of the chimneys just referred to.

The dimensions of these pipes should be determined on the condition that the velocity in them should be from 3 to 4 feet a second.

In small theaters, a single chimney will usually suffice for all the galleries. The calculation of the dimensions to be given to the foul-air openings should be made for each gallery separately, from the corresponding number of spectators.

The cast-iron smoke-pipes of the heaters should be carried into the ventilating-chimneys, keeping them separate throughout their whole height; and at the lower part of the chimney a grate should be placed, to be used whenever required, to increase the draught, especially in summer. It would not be prudent, even in winter, to count upon the heat transmitted by the smoke-pipe to produce a sufficiently powerful draught.

The sectional area of the chimney should be calculated so that the mean velocity in it may be 5½ or 6 feet a second.

They should open, when possible, in a cupola placed above the center of the hall, which should also receive all the ventilating-pipes of the upper stories.

A main ventilating-chimney should be constructed of brick and not of metal, above this cupola, the latter to be as low as possible, while the chimney should be made as high as the nature of the building will permit, but at least 20 or 25 feet.

The sectional area of this chimney should be calculated on the condition that the mean velocity of the draught in it should be about 6½ feet a second.

127. *Utilization of the heat given out by the lights.*—In addition to the pipes for carrying off foul air, the gases produced by the burners of the main chandelier or the other chandeliers suspended from the ceiling should also be carried into the cupola. The pipes intended to carry the gases there should be made as small as possible in order not to change the direction of the main draught in the vicinity of these places.

The diameter of the ventilating-pipe above a chandelier placed near the ceiling and supplied with a metal or glass reflector should be calculated under the condition that it shall only remove 150 cubic feet of air an hour with the velocity of 13 feet a second to a cubic foot of gas consumed by the chandelier.

The single burners in the boxes and corridors should take the air necessary to support the combustion in the interior of the boxes or from the adjoining ventilating-pipes. It will suffice to make their ventilating-pipes ½ or ¾ inch in diameter.

If, as is most probable, the plan of lighting through a glass ceiling, tried at the Théâtre du Cirque and the Lyric Theater, be not adopted, it will be advisable to place a circle of gas-jets at the base of the ventilating-chimney, to be used only to increase the draught in summer, when the elevation of the temperature of the external air tends to reduce it. It may be assumed that under similar conditions each cubic foot of gas consumed will carry off about 800 cubic feet of air.

A valve should be placed at the foot of the chimney to moderate its draught, and particularly to stop the draught after the close of the play, to prevent useless loss of heat and the entrance of cold air during the night.

128. *Ventilation of the stage.*—For theaters where great quantities of smoke are frequently produced during sham fights, grand illuminations, displays of fire-works, &c., it is well to keep up a strong draught in the upper part of the stage, in order to prevent the gases from being drawn into the auditorium by the draught kept up there, as happened at the Châtelet Theater, where these precautions were not taken. Further-

more, in order that this stage-ventilation may not interfere with that of the body of the house, it is necessary to connect the two systems with each other.

For this purpose, a chimney or an auxiliary ventilating-flue should be made above the stage and joined with the main chimney, the draught of which should be increased by means of gas-jets lighted at the proper time, a little while before the smoke is produced.

129. *Precautions to be taken to prevent re-entry of the external air on the stage.*—The introduction of external cold air on the stage should also be avoided, in order that currents from the stage to the hall may not be produced, which would be disagreeable both to the actors and to the audience. This result has taken place at the Théâtre du Cirque, where large openings in direct communication with a court and public way have not been closed.

130. *Lighting-apparatus for the auditorium.*—Without wishing to specify here the arrangements to be adopted for lighting theaters, we will confine ourselves to stating that glass ceilings, which require to be ornamented with colored designs, occasion a considerable loss of light, while they produce in the room an amount of heat very unpleasant for the spectators in the upper tiers, and which is also very expensive for the directors, who are naturally led unduly to restrict the number of gas-jets, thus rendering useless the expense gone to in introducing this method of illumination. Although this consumption, even when thus restricted, assists the removal of foul air, the amount carried off is seldom more than 450 cubic feet to a cubic foot of gas burned, while with suitable arrangements the amount of 600 to 800 cubic feet of air might be carried off to every cubic foot of gas.

131. *Arrangements to be made to secure and regulate the amount of warmth and ventilation.*—Warmth and ventilation can only be properly secured by an attentive observation of atmospheric conditions and of the number of spectators, and by prompt application of the proper means. There is, in fact, no difficulty in the arrangement or the management of the apparatus; but it is necessary to take care, and not to trust to ordinary firemen, nor even to the managers of theaters, always interested in using as little coal and gas as possible.

It is then indispensable to confide this trust to special agents, responsible directly for the authority and the regularity of the service, and obliged to make daily reports. Without such control, independent of theatrical managers, the best apparatus may give imperfect results or even fail entirely.

132. *Application.*—The preceding rules have been adopted, after long discussion and many experiments,* to serve as bases for the plans to be adopted at the Lyric Theater and the Châtelet Theater. The city

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* The commission charged with the investigation of the question and the examination of projects was composed of Dumas, member of the Institute, president; Chaix-d'Est-Ange, Pelouse, Rayer, Gilbert, Caristie, Baltard, General Morin, members of the Institute; Grassi, chemist.

government has scarcely any control over the latter, and but little over the former. Still, as the results obtained at the Lyric Theater have, in the main, been somewhat satisfactory when the apparatus has been properly managed, I will describe this first application, in spite of its imperfections.

The auditorium, intended to accommodate 1,700 spectators, has really but 1,472 seats, distributed as follows:

Orchestra, parquet, and lower boxes		440
First tier	256	
Second tier	302	
Third tier	178	
Fourth tier	296	1,032
		1,472

The amount of air to be renewed for each spectator had been limited to 1,060 feet an hour, which, with the above number of places, corresponded to a total volume of 1,560,000 cubic feet an hour. The conditions imposed upon the contractor, based on the hypothesis of 1,700 spectators, would require a renewal of 1,800,000 cubic feet of air an hour.

133. *External-air supply.*—The air-supply was taken in St. Jacques Square from a circular well 12 feet in diameter, which, by a subterranean passage, at first circular, 11 feet in diameter, and afterward of variable form, but of the same sectional area, carried it to the subbasement of the building, and spread it over the whole extent occupied by the heaters and the air-chambers. The sectional area of the passage-way was therefore but 98 square feet; and experiment (December 9, 1862*) having shown that the velocity in it was as much as 6 feet a second, the volume of fresh air introduced by this gallery was that day 1,090,000 cubic feet. It was only deemed necessary to introduce 1,060,000 cubic feet, since the unavoidable admission of air through the doors, the passages, and the stage would easily and without inconvenience furnish the balance, as has been found to be the case. It would, nevertheless, be more prudent in such cases to calculate the dimensions of the fresh-air trunk to furnish the entire amount.

134. *Alteration of the adopted plans.*—But a little while after the opening or the lease of the theater to the manager, the external fresh-air passage was closed, and even the pit in St. Jacques Square covered with ivy. Thus the introduction of air by these passages, as well as by the pipes leading to the interjoists of the boxes, is almost entirely prevented, while the outward draught is as strong as ever. It therefore follows that, to replace the air carried off, cold air enters through the halls, passages, &c., which is very unpleasant for the spectators, and which the public attribute to the general arrangements adopted, while they are only the result of want of care and of the exercise of authority.

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* *Études sur la ventilation, vol.* 2.

In spite of the influence which these changes, and others equally serious, in part of the apparatus have had on their operation, I will describe the results which have been obtained by continuous service when the ventilation has been regularly kept up.

135. *Ground-floor.*—Part of the air supplied by the air-trunks passes into two heaters placed under the main hall; the rest flows into two mixing-chambers, having together a capacity of 6,500 cubic feet. The two heaters have a sectional area of 97 square feet, and the amount of warm air which they can supply to the mixing-chamber being at a maximum 883,000 cubic feet an hour, or 245 feet a second, this corresponds to a velocity of 2½ feet a second.

From the air-chamber, and from each of its compartments, branch off six pipes, of which—

Two are intended to supply fresh air to the different galleries.

Two were to supply air entering the room by the floor of the stage, concentric with the foot-lights. This method of introduction had to be abandoned, as it was unpleasant to the musicians.

Two were to carry air in vertical pipes placed by the stage-opening against the wall which separates it from the auditorium.

There are, in addition, four heaters for warming the vestibules, the staircases, waiting-rooms, dressing-rooms, &c.

136. *Removal of foul air.*—In the orchestra and parquet, the air is drawn off under the floor by 101 openings, having altogether a clear area of about 65 square feet. The passage under the floor, which should have had a clear area of 118 square feet, has been reduced to 40 square feet.

The air drawn off at this height, carried by two pipes to the right and left, is drawn to two ventilating-chimneys, which contain the smoke-pipes of the heaters of the hall, and may also, when necessary, be heated by a small special fire.

Direct experiments, made during five consecutive evenings in May, 1863, with external temperatures comprised between 56° and 73°, have shown that a mean consumption of 441 pounds of coal, costing about $2 for each performance, effects the removal of about 600,000 cubic feet of air an hour, which corresponds to about 1,400 cubic feet to a seat. By means of this abundant ventilation, the temperature of the orchestra and parquet may be maintained within proper limits.

But the managers of the theater do not use the two ventilating-chimneys; and if they have not been closed, instead of promoting the removal of foul air, they may cause the entrance of cold air, in consequence of a reversal of the direction of the motion of the air caused by the greater power of the upper draught.

For the first, second, third, and fourth galleries, the foul air is carried out at the floor of the galleries or through the steps of the amphitheater, as was remarked in § 126; and the observations made in May, 1863, have shown that the amount of foul air extracted at the base of the cupola was as much as 1,361,000 cubic feet for 736 places, equal to 1,848 cubic feet to a place. For the whole audience-room, containing 1,472 places, the total amount of air removed on an average during the five evenings in May, 1863, when the observations were made, was as much as 1,970,000 cubic feet, or 1,338 cubic feet instead of 1,060, which was all demanded. The total amount was even raised on December 3, 1862, to 2,121,000 cubic feet an hour.

137. *Maintenance of equality of temperature in the different galleries.*—I have given in my investigations in regard to ventilation[*] the results of experiments which have been made under very different temperatures, and which have shown that the results obtained have exceeded what was required as to the amount of air removed from the room at the different galleries. The results relative to keeping up the temperature have not been less satisfactory. In fact, by means of this regular ventilation, the temperature at the different galleries has been maintained at a very remarkable state of uniformity, as shown by the following results for the first and fourth galleries, which alone will be cited here:

Date.	Mean external temperature.	First gallery, mean temperature.	Fourth gallery, mean temperature.
	° F.	° F.	° F.
May 24, 1863	52.25	69.10	69.80
May 25, 1863	55.85	71.60	74.66
May 26, 1863	55.85	71.60	72.05
May 27, 1863	59.90	75.02	75.02
May 28, 1863	62.60	75.92	76.64
May 29, 1863	67.10	76.10	77.36
May 30, 1863	69.80	78.26	80.06

It is well to repeat that in a place strongly ventilated a temperature of 75° does not feel unpleasant, and that if the direct external air-openings required for the summer season have been made it will be easy, if required, to obtain a still smaller difference between the external and internal temperatures.

At the old Opera, the Italian Theater, and most of the unventilated theaters, it is not unusual to observe temperatures of 95° and 105°.

138. *Temperature on the stage.*—When the heaters designed to warm the stage are well managed, a proper degree of temperature may always be maintained there. Thus, in November, 1863, with an external temperature of 39°, was obtained—

	° F.
On the stage	66.02
In the orchestra-stalls	70.88
In the gallery-boxes, (average)	72.32
In the amphitheater, (fourth gallery)	73.94

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[*] *Études sur la Ventilation, vol. 2.*

In May, with external temperatures of from 64° to 68° at 7 o'clock, and from 55° to 57° at midnight, the temperature on the stage was on an average 71° to 73°.

139. *Volume of air carried off at the cupola to a cubic foot of gas burned.*—During the experiments of May, 1863, the volume of gas burned an hour in the main room was on an average 2,940 cubic feet, and the volume of air was 1,361,000 cubic feet, which corresponds to 462.5 cubic feet of air carried off by a cubic foot of gas consumed. But in the above-mentioned consumption is included that of a large number of burners which had no direct influence on the ventilation. A removal of 600 to 800 cubic feet of air to a cubic foot of gas directly consumed to produce it may be calculated upon when proper arrangements are made.

140. *Consequences of the preceding facts.*—The results of direct experiment made in different seasons show that the arrangements adopted for warming and ventilating the Lyric Theater are capable of producing satisfactory results. The same is true of the Gaîtés.

It is a pity to see the public, in consequence of the senseless parsimony of the manager of a theater, deprived of the advantages which the administration of the city of Paris has, at considerable expense, undertaken to secure them.

STABLES AND COW-HOUSES.

141. The capacity of stables should be 1,800 cubic feet to each animal; this was the proportion adopted in 1841 by the war-minister for cavalry-stables. In all constructed since that time for the army-service, the width allowed for each horse is about 4¾ feet.

This increase of space produced from 1835 to 1858 a reduction in the number of horses lost in 1,000, from 51 deaths by glanders in the period from 1835 to 1845 to 10 only during that from 1845 to 1858, and from 94 deaths from all diseases in 1835 to 1845 to 22 only from 1848 to 1858.

Large corporations, such as the General Omnibus Company and the railroad-companies, are then wrong in restricting the capacity of their stables to 700 or 900 cubic feet of air to a head.

142. *Permanent opening of doors and windows.*—Experiments carried on for several years in cavalry-regiments in garrison in the north, center, or south of France, have proved that horses have better health and greater strength when kept in stables where the doors and windows are constantly kept open night and day in all seasons than where they are kept shut. Similar observations have been made in stables containing a great many cattle, which are thus relieved from epidemic affections of the respiratory organs.

143. *Amount of air to be allowed.*—When stables are not arranged so as to admit air throughout their whole length and by two opposite walls, it is proper to make in the roof at the middle of the alleys, if they are double or above the passage behind the horses, ventilating-chimneys of brick sufficiently large to secure a ventilation of 6,400 to 7,000 cubic feet

of air an hour to a horse, with a velocity of 28 inches a second, which may be produced by a difference of temperature of 11° to 13° between the external air and that of the stable. This requires that the chimneys have a sectional area of 108 to 124 square inches to a horse.

By means of this ventilation, the hygrometrical condition of the air in the stable will be maintained within convenient limits.

144. *Use of gas-burners.*—The ventilation of stables may be increased by making use of the heat given out by gas-burners used to light them up at night, which then allows of reducing the sectional area of the ventilating-pipes.

145. *Cow-houses.*—What precedes relates to work-animals. In the case of milch-cows, it appears that a certain drowsy laziness is favorable to the production of milk; and in such cases it is necessary to limit the ventilation to what is absolutely necessary for health.

MEANS OF CONTROL.

146. *Means to be used to determine the condition and the results of a system of ventilation.*—It has been shown by the numerous examples that precede that the establishment of a complete and regular renewal of air in occupied places in reality presents no difficulty, and that the rules to be followed are very simple. Their application will be equally so, and will involve but little expense if architects take care to devise plans of ventilation at the same time that they make the plans for construction, instead of waiting till the building is almost finished.

But when all the arrangements have been made to secure the renewal of air, the first thing to do is to examine whether the desired results have been obtained, and the second is to regulate the operation of the apparatus.

To determine what are the amounts of air carried off and drawn in, a small portable instrument is used, called an anemometer, consisting of a wind-mill with light and easily-moved vanes, connected with gear-wheels and pointers, which indicate the number of turns made by the vanes in a given time.

Experiments show that with an apparatus of this kind the velocity of the air may be deduced from the number of turns of the wings by means of an equation of the form:

$$V = a + b\,N$$

V being the velocity in a second;

a, a constant term, expressing the velocity of the air at which the instrument commences to move;

b, a constant number;

N, the number of turns indicated in a second.

Thus, one of the anemometers of the Conservatory has the formula:

$$V \text{ (in inches)} = 8.66 + 7\,N$$

This instrument should be placed, as far as possible, in a part of the flue traversed by the air, where the velocity is uniform and well regulated. It should be kept in operation at least two minutes, if a watch indicating seconds be used ; and four or five, if a watch indicating minutes only is employed. From the number of turns made in this interval of time may be deduced that corresponding to a second, whence the velocity, V, may be obtained. This velocity, multiplied by the sectional area of the flue, will give the amount of air passing through in a second, and from this the amount passing through in 3,600 seconds, or an hour, can be obtained.

If it be feared that the velocity in the flue is variable, on account of its large size or other circumstances, it will be necessary to try the instrument at different places, which will then give with sufficient exactness the mean velocity of the air.

When it is desired to determine the volume of air which is carried out or drawn in through an opening covered with a grating, the anemometer should not be placed above or in front of this opening, as is done by many observers, and the velocity resulting from the number of turns observed taken as the mean velocity of the air passing through. Serious errors will result from this method. The proper way is to place before the opening, and fitting to it as closely as possible, a pipe having at one end the form of the opening, and joining at the other end a cylindrical pipe at least 2 feet long, in which the anemometer should be placed, which would then indicate the velocity of passage in this part of the auxiliary pipe. The velocity of the air introduced or withdrawn in a second or an hour may easily be deduced afterward.

147. *Means of insuring the regularity of the ventilation.*—While the use of portable anemometers serves for experimental investigations and for the determination of the results obtained by the ventilation, it is not sufficient to secure the necessary regularity of ventilation in large establishments.

In such cases it is necessary to introduce much larger anemometers, connected with an electrical recording-apparatus placed in the office of the superintendent, or in a conspicuous place where it can be seen every hour, or every morning and evening, whether the renewal of air is proceeding with regularity and with the prescribed energy.

This is not the place to describe the apparatus.* I confine myself to stating that an anemometer of the kind has been employed with success for several years at the Conservatory of Arts and Trades, to insure regularity in the ventilation of the lecture-rooms; and that every year it works for about five consecutive months without derangement, and without requiring any care but the renewal of the solutions in the battery two or three times a season.

A similar anemometer has been in constant operation for several months in the ventilating-chimney at Lariboisière Hospital, and has served to show, every morning, the amount of foul air removed from a wing containing 106 beds, during the night, and, every evening, the amount during the day.

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* See the *Annales du Conservatoire*, vol. 5, 1864, p. 341.

Methods of observation of this kind, automatic and independent of the personal action of the employés, are the indispensable adjuncts of great ventilating systems, if it be desired that the service be performed in a regular manner. They also serve to render the work of inspection by the heads of the establishment more easy and efficient.

Errata in previous portion of this article contained in the report for 1873:

In § 31, pp. 308, 309, for 1,000 *cubic feet weigh*, read *one cubic foot weighs*; and for *weight of* 1,000 *cubic feet*, read *weight of one cubic foot.*

In § 35, pp. 310, 311, for 0.0000756, 0.000081, 0.000005, 0.000077, 0.000074, 0.000003, read 0.0756, 0.081, 0.005, 0.077, 0.074, 0.003 respectively.

ETHNOLOGY.

[It is considered important to collect all possible information as to the location and character of ancient earth-works, which exist in various parts of the United States, with a view to classify them and determine their distribution in relation to special topographical features of the country as well as to different regions. For this purpose the correspondents of the Institution are respectfully requested to furnish information as to any ancient remains of this character existing in their neighborhoods.—J. H.]

ANCIENT GRAVES AND SHELL-HEAPS OF CALIFORNIA.

By Paul Schumacher.

During my visit to that part of the California coast between Point San Luis and Point Sal, (Map A,) in the months of April, May, and June, of 1874, I often had occasion to observe extensive shell-heaps, like those I had found about a year previously so numerous along the shores of Oregon. These deposits of shells and bones are the kitchen refuse of the earlier inhabitants of the coast regions, where they are now found, and, though differing from each other in their respective species of shells and bones of vertebrates, according to the localities and the ages to which they belong, they have still, together with the stone implements found in them, a remarkable similarity in all parts of the North American Pacific coast that I have explored—a similarity that extends further to the shell-heaps or "*Kjökken-möddings*" of distant Denmark, as investigated and described by European scientists.

In Oregon, from Chetko to Rogue River,[*] I found that these deposits contained the following species of shells: *Mytilus Californianus*, *Tapes staminea*, *Cardium Nuttallii*, *Purpura lactuca*, &c.; eight-tenths of the whole being of the species first mentioned.

In California, on the extensive downs between the Arroyo Grande and the Rio de la Santa Maria, the mouth of which latter is a few miles north of Point Sal, I found that the shells, on what appear to have been temporary camping-places, consist nearly altogether of small specimens of the family *Lucina;* so much so that not only can scarcely any other sort

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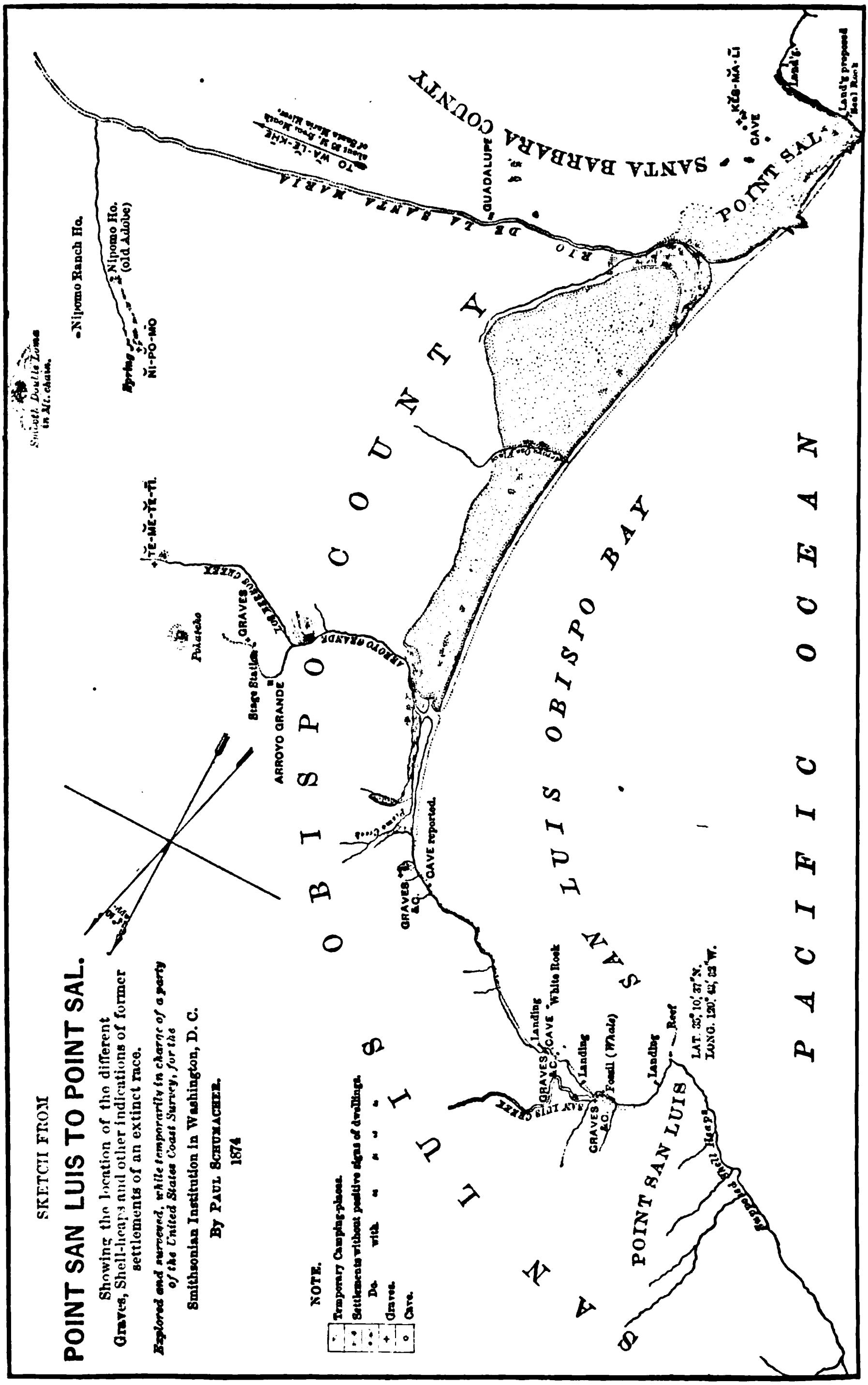
[*] Of the collections made by the writer at that place, the complete and illustrated description will be found in the Smithsonian Report for the year 1873, p. 354.

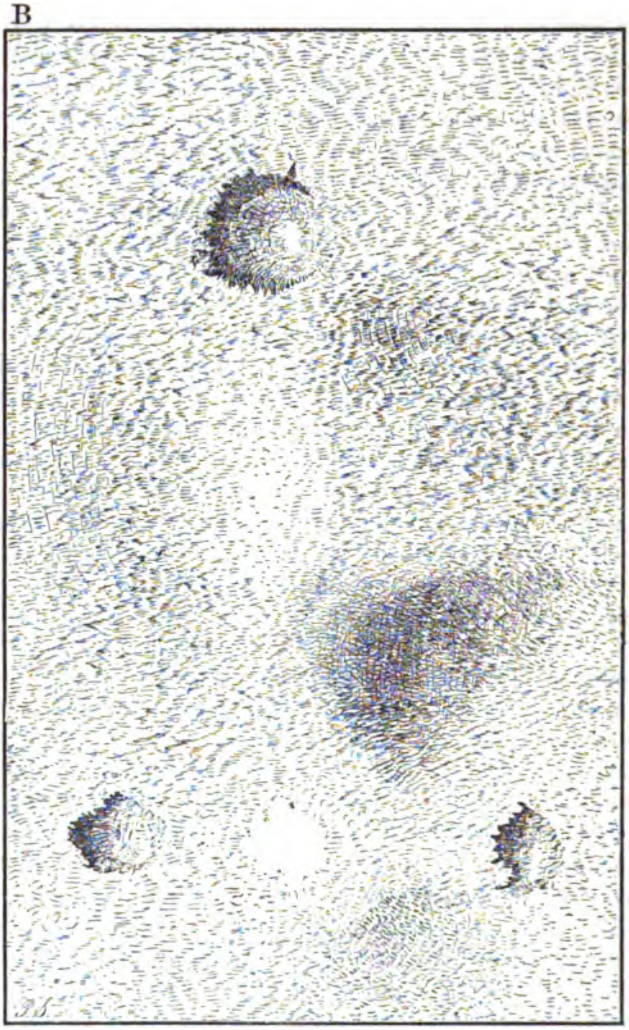

SKETCH FROM
POINT SAN LUIS TO POINT SAL.
Showing the location of the different Graves, Shell-heaps and other indications of former settlements of an extinct race.
Explored and surveyed, while temporarily in charge of a party of the United States Coast Survey, for the Smithsonian Institution in Washington, D. C.
By PAUL SCHUMACHER.
1874
NOTE.
Temporary Camping-places.
Settlements without positive signs of dwellings.
Do. with " " "
Graves.
Cave.
PACIFIC OCEAN
SAN LUIS OBISPO BAY
SAN LUIS OBISPO COUNTY
SANTA BARBARA COUNTY
POINT SAL
POINT SAN LUIS
RIO DE LA SANTA MARIA
TO WA-LE-KHE about 20 M. from Mouth of Santa Maria River
GUADALUPE
KSA-MA-LI
CAVE
Land'g
Land'g proposed Rail Road
Nipomo Ranch Ho.
Nipomo Ho. (old Adobe)
Spring
NI-PO-MO
Double Loma in Alt. chain
TE-ME-TE-TI
LOS BERROS CREEK
GRAVES
Pohateko
ARROYO GRANDE
Stage Station
ARROYO GRANDE
CAVE reported
GRAVES &C.
White Rock
Landing
CAVE
GRAVES &C.
SAN LUIS CREEK
Landing
Fossil (Whale)
GRAVES &C.
Landing
Reef
LAT. 35° 10' 37" N.
LONG. 120° 43' 13" W.
Shell Heaps
Exposed

be found, but hardly even any bones. My reason for supposing these heaps to be the remains of merely temporary camps, is the small number of flint knives, spear-heads, and other implements found therein, and the total absence of any chips that might indicate the occasional presence of a workshop where domestic tools and weapons of war were manufactured—a something that immediately strikes the accustomed eye in viewing regularly well-established settlements. On further examining this class of heaps by a vertical section, we find layers of sand recurring at short intervals, which seem to indicate that they were visited at fixed seasons; those *möddings* exposed toward the northwest being vacated while the wind from southwest was blowing sand over them, and, *mutatis mutandis*, the same happening with regard to camps with a southwest aspect while the northwest wind prevailed. It is fair, then, to suppose that these places were only the temporary residences of the savages to whom they appertained; that they were tenanted during favorable times and seasons for the gathering of mollusks, which, having been extracted from their shells, were dried in the sun for transportation to the distant permanent villages. The comparatively small quantities of shell-remains now found at these regular settlements going also to support this theory. No graves have been found near these temporary camps. I discovered, however, one skeleton of an Indian, in connection with which were thirteen arrow-heads, but it was plainly to be seen that the death of this person had happened during some short sojourn of a tribe at this place, as the burial had been effected in a hasty and imperfect manner, and the grave was without the usual lining which, as we shall see, is found in all the other tombs of this region.

On the extremity of Point Sal, the northern projection of which is covered by large sand-drifts, we find, down to the very brink of the steep and rocky shore, other extensive shell-deposits, which, with few exceptions, consist of the *Mytilus Californianus* and of bones; flint chips being also found, though very sparsely in comparison with the mass of other remains. The sea having washed out the base of this declivity, and the top-soil having, as a consequence, slid down, we see on the edge of the cliff shell-layers amounting in all to a thickness of four or five feet; that part closest to the underlying rock appearing dark and ash-like, while the deposit becomes better preserved as the surface is neared. At other places, for example, on the extreme outer spur of this Point Sal, the shell-remains have been so conglomerated or cemented together by extreme antiquity as to overhang and beetle over the rocks for quite a distance.

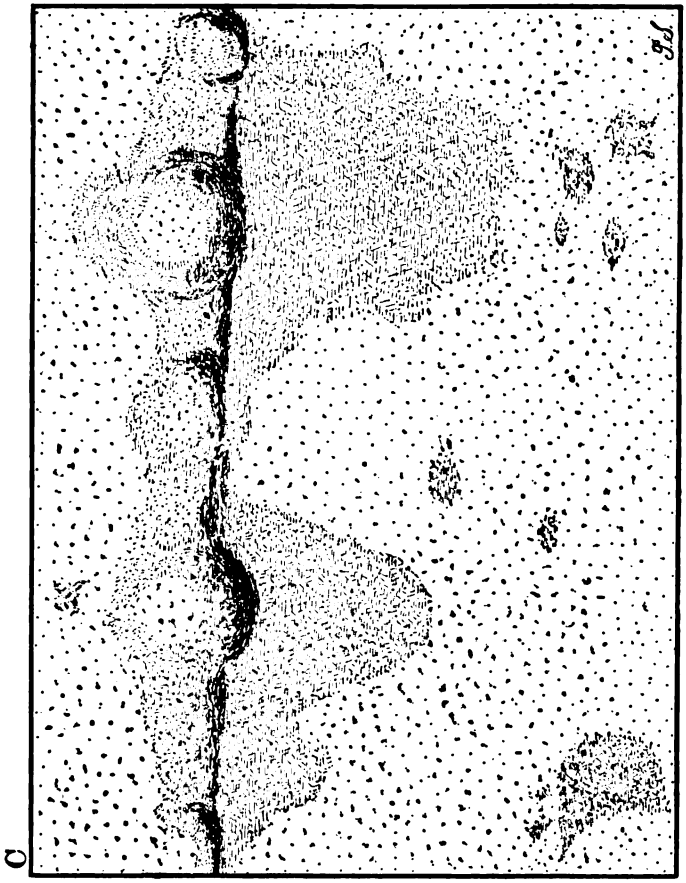
Leaving the temporary camps, we shall visit the regular settlements of the ancient aborigines. Traces of these are found near the southern Point Sal, at a place where it turns eastward at an angle of something less than 90°, behind the first small hill of the steep ridge which trends easterly into the country, and which, up to this spot, is, on its northern slope, covered with drift-sand and partially grown over with stunted herbage, (Fig. 2.) Further traces of a like kind are to be seen on the high bluff between North and South Point Sal, (Fig. 3.) Here the shells are

Fig. 2.



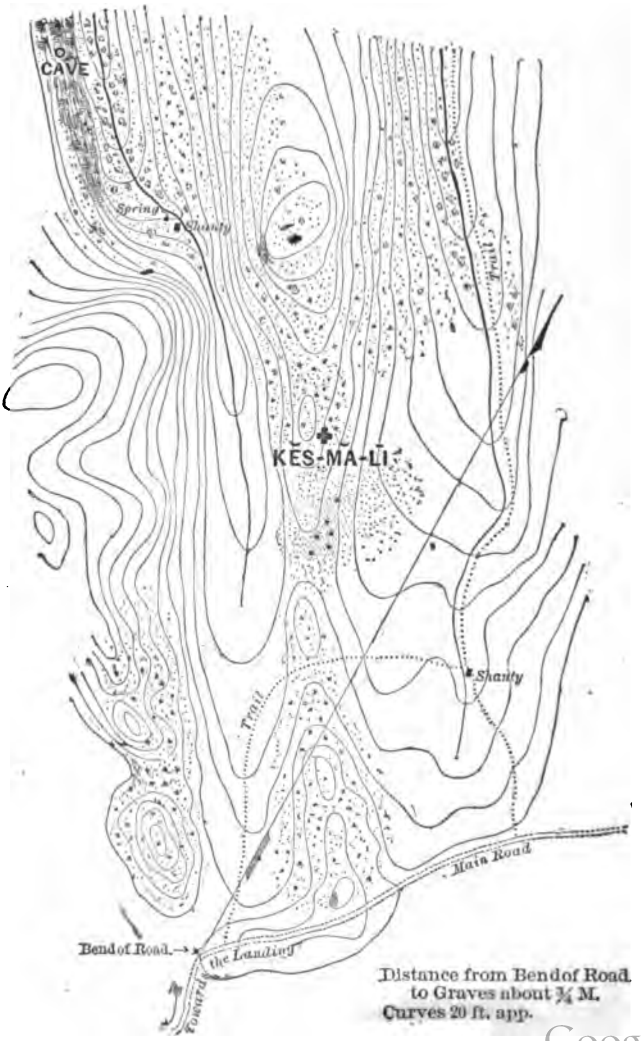
piled up in shapeless, irregular heaps, as they are met in all localities on the coast where there were the fixed dwelling-places of people whose principal food consisted of fresh shell-fish; for in the neighborhood of these permanent homes the shell-remains were always put away in fixed places, while in temporary camps they were carelessly distributed over the whole surface of the ground. Very vividly did these bleached mounds recall to my mind the immense remains of such heaps as I had seen in Oregon, on the right bank of the Chetko, as also near Năt-ĕ-nĕt, and near Crook's Point, Chĕtl-ĕ-shīn, close to Pistol River. I remembered, also, how I had observed the Indians in various places; for example, near Crescent City, on the Klamath, and on the Big Lagoon, forming just such shell-heaps; two or three families always depositing their refuse on the same heap.

Fig. 3.



To return to Southern California. A deposit similar to that of Point Sal, although much smaller, is found on the left bank of the Santa Maria River, near its mouth. Both at the first-described fixed camps and at this place there are to be found tons of flint-chips, scattered about in all directions, as also knives, arrow-heads, and spear-heads in large numbers. I was somewhat disappointed, however, in being unable to find any graves; such numerous heaps indicating the existence of important settlements, that should have been accompanied by burying-places. I therefore moved farther inland, seeking a locality where the soil could be easily worked, where a good view of the surrounding country could be had, and where, above all, there was fresh water, all of which requirements appear to have been regarded as necessary for the location of an important village. I soon recognized at a distance shell-heaps and bones, the former of which become scarcer as we leave the shore. Approaching these, on a spur of Point Sal, upon which a pass opens through the coast-hills, and on both sides of which are springs of fresh water, though I did not succeed, after a careful examination, in distinguishing the remains of a single house, I think I found the traces of a large settlement on a kind of saddle on the low ridge, where flint-chips, bones, and shells lie in great numbers. At length search revealed to me in the thick *chaparral* a few scattered sandstone slabs, such as in that region were used for lining graves. Digging near these spots, I at last found the graves of this settlement, called by the old Spanish residents call KĔS-MĀ-LĪ. (Fig. 4.)

Fig. 4.



Distance from Bend of Road to Graves about ¾ M.
Curves 20 ft. app.

Here were brought to light about one hundred and fifty skeletons and various kinds of implements. The graves were constructed in the following manner: A large hole was made in the sandy soil to a depth of about five feet; then a fire was kept in it until a hard brick-like crust was burned to a depth of four or five inches into the surrounding earth. The whole excavation was then partitioned off into smaller spaces by sandstone slabs, about one and a half inches thick, one foot broad, and three feet long; in which smaller partitions the skeletons were found. One of these slabs generally lay horizontally over the head of the corpse, as a kind of protecting roof for the skull, just as I found them at Chetko River, although in the latter place the graves were lined with split redwood boards instead of stones. Such careful burial is not, however, always met with, and must evidently be taken as a sign of the rank or the wealth of the deceased; the more so, as in such graves I usually found many utensils, which is not the case with the more carelessly formed tombs, which were covered with a piece of rough stone or half a mortar. The slabs above mentioned were generally painted, and a piece which I carried off with me was divided lengthwise by a single straight, dark line, from which radiated, on either side, at an angle of about 60°, thirty-two other parallel red lines, sixteen on each side, like the bones of a fish from the vertebræ. In most cases the inner side of the slab was painted red. Unluckily the specimen I took with me became wet, by rain, before I was able to convey it to a place of safety, and the previously-well-preserved design was blurred.

In these graves the skeletons lay on their backs, with the knees drawn up, and the arms, in most cases, stretched out. No definite direction was observed in the position of the bodies, which frequently lay in great disorder, the saving of room having been apparently the prime consideration. Some skeletons, for example, lay opposite to each other, foot to foot, while adjoining ones, again, were placed crosswise. The skeletons of females have, instead of the protecting head-slab, a stone mortar or a stone pot placed on its edge, so as to admit the skull, which latter, if too narrow in the neck to admit the skull, is simply buried underneath it. Cups and ornaments, both in the case of men and women, lie principally about the head, while shell-beads are found in the mouth, the eye-sockets, and in the cavity of the skull, which latter is almost always filled with sand, pressed in through the *foramen magnum.* The skeletons were, in some cases, packed in quite closely, one over another, so that the uppermost were only about three feet below the surface of the ground. The indications of poverty are very evident in regard to these, in the scarcity of ornaments, except, perhaps, when they are females, as they are in the majority of cases. I cannot accept the hypothesis that these were the slaves of some rich man and buried with their master; for the lower skeletons were generally found to have been disturbed in a very singular manner, such as could only have been occasioned by a re-opening of the grave after the decomposition of the bodies. I found, for example, a lower jaw lying near its right place, but upside down, so that both the upper and the lower teeth pointed downward; in another case the thigh-bones lay the wrong way, the knee-pans being turned toward the basin; and, in other instances, the bones were totally separated and mixed up; all tending to show that the graves had been repeatedly opened for the burial of bodies at different times. Once I even found, upon piercing the bottom-crust of a sepulchre, another lying deeper, which, perhaps, had been forgotten, as the bones therein were somewhat damaged by fire. Plenty of charcoal is found in these tombs, usually of redwood, rarely of pine, and I could not determine any third variety. Sometimes there were also discovered the remains of posts from three to six inches in diameter, and of split boards about two inches in thickness. These are probably the remains of the burned dwelling of the deceased, placed in his grave with all his other property, after the fashion I observed in Chetko last year.

I examined other graves resembling those described at Point Sal. These others are known by the name of Tĕ-mĕ-tĕ-tī. They lie about fourteen miles north of the Point Sal graves, and are situated on the right bank of the Arroyo de los Berros, opposite to the traces of former settlements about seven miles inland. These tombs only differed from those of Kĕs-mă-tī in not being lined with the thick burned brick-like crust mentioned above, but with a thin light-colored crust, slightly burned, and not more than a quarter of an inch thick.

To these graves I paid a second visit, hoping to obtain more material, having been there only a very short time at my first visit. But the proprietor of the land disappointed my desires, for he appeared, in spite of my scientific explanations, to be inclined, according to squatter-fashion, to prevent, with his rifle, my visit to the land, to which he possessed no title. These were the graves where I found the bronze cup, and a buckle of the same material, which later, I am sorry to say, was unaccountably lost. I had hopes to discover more of such articles, enabling me to trace the connections of these people. The location of this village is rather hidden; it is situated on a small plain between a bluffy elevation on the left bank, and the rather high and wooded right banks of the Los Berros Creek. I could plainly notice the excavations where houses had formerly stood, and particularly the large sweat-house.

In company with the well-informed and industrious antiquarian, Dr. W. W. Hays, and Judge Venabel, of San Luis Obispo, I explored another aboriginal settlement known by the name of Nī-pŏ-mō. It is situated on the large rancho of like name, about eight miles inland, and distant about a mile and a half from the Nipomo Ranch House, occupied by the hospitable Dana brothers. These graves are also in sandy soil, near a former settlement, the existence of which is well marked by quantities of flint-chips, fragments of tools, bones, and a few shells. Only about three hundred yards from the graves, and nearly in a straight line with them and one of the houses of Nipomo Ranch, there is a large spring of good water, surrounded by willows. These graves were indicated by an elder-bush, a plant which I always found near the graves, or in the neighborhood of ancient settlements.

Lastly, I examined the Wă-lĕ-khe settlements, (Fig. 5.) I hesitated to undertake the trip to these graves, because I only had four days left before the departure of the steamer; and consequently I would only have about six hours remaining for work. But, as I supposed this country offered much of interest to the explorer, I made only the following examination:

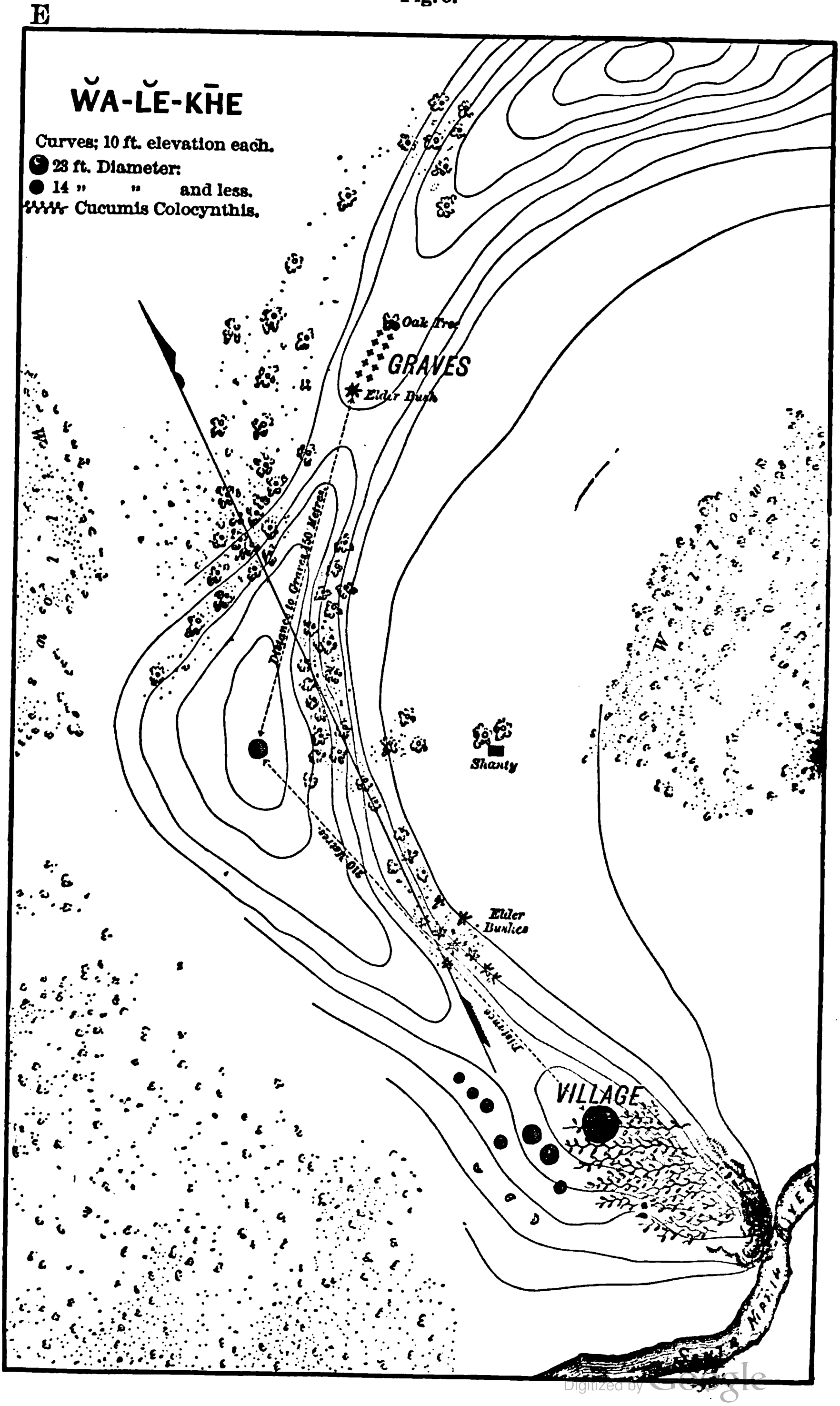
About twenty-five miles from the mouth of the Santa Maria River the Alamo Creek empties into it, discharging a large amount of water. Following the wide bed of the Santa Maria for about seven miles farther up stream, we reach a smooth elevation, which at this place rises about sixty feet above the bend of the river, and which trends in a curve toward the mountains on the right bank. At the farthest end of this, at a place where a fine view over the whole valley is had, we find the traces of the ancient village, now known as Wă-lĕ-khe. A short distance from the former dwellings, on the highest point of the ridge, an excavation marks the spot where once a house stood, probably that of a chief.

I started from San Luis Obispo to visit this place, passing by the remarkable tar-springs, which are situated at about a distance of eighteen miles from the town. Near them I found traces of what had formerly been a large ditch. As before stated, I had not time to make thorough examinations, yet I found that the ditch was still three feet wide, and entered the creek some miles above the tar-springs, on the banks of which creek the said springs are found in different places. Near the road I observed, in the middle of the ditch, an oak-tree, measuring twelve inches in diameter, and which plainly had taken root after the abandonment of the ditch; for it was not torn up, as would have been caused by the running water, but was at this place well preserved.

I also visited Ostion rancho, (sometimes called Ranchito,) at which place there are extensive beds of oyster-shells, and also some other species of shells, among which are prominently *Tapes*. At one place, about fifty yards from the right bank of the Arroyo Grande, the shells are closely packed and bound together with coarse sand, forming quite an extensive bluff. I collected a few specimens, which I presented to the California Academy of Sciences.

At the place where Alamo Creek empties into the Santa Maria River, on its left bank, I found several earth-works, and they appeared to me to have been built on this level but elevated spot, the entrance of the valley, for defensive purposes. During my hasty examination I could not discover any place where a house might have been, nor any graves, but nevertheless I incline to the belief that near this place had been an important settlement; for Alamo Creek has better drinking-water than the Santa Maria River, and its width and the adjoining country form

Fig. 5.


E
WA-LE-KHE
Curves; 10 ft. elevation each.
● 23 ft. Diameter:
● 14 " " and less.
Cucumis Colocynthis.
Oak Tree
GRAVES
Elder Bush
Distance to Graves 150 Metres
210 Metres
Shanty
Elder Bushes
Distance
VILLAGE
Main River

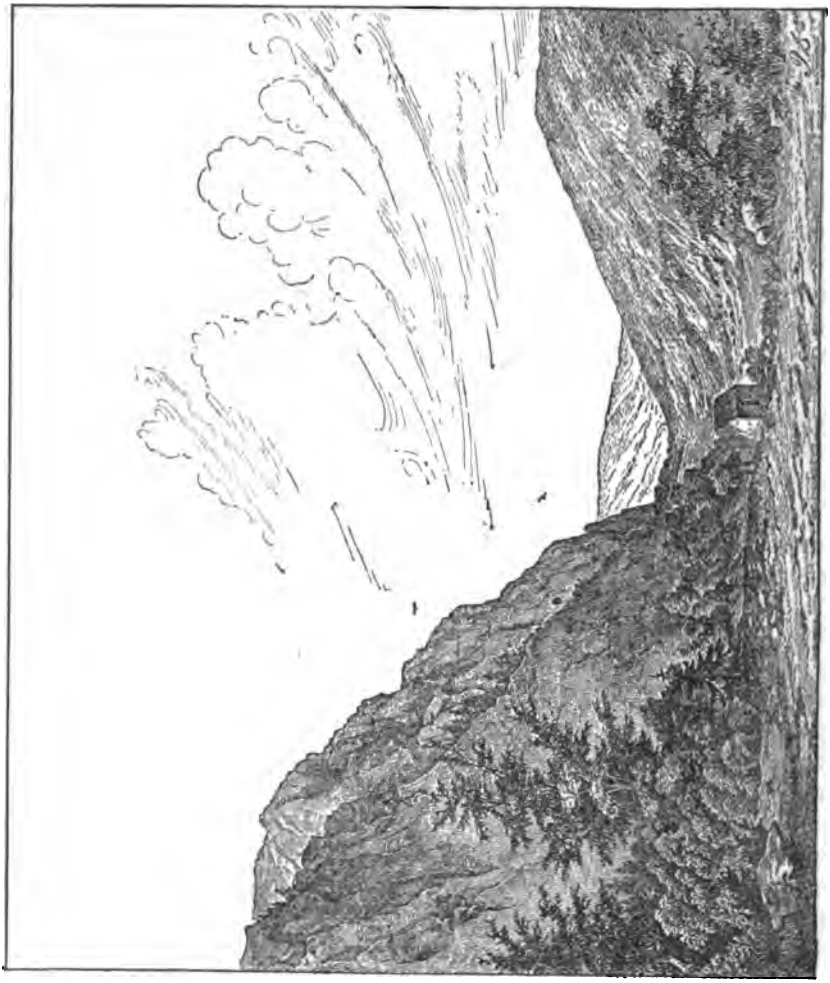
quite a picturesque landscape, which, together with the excellent hunting-ground, is really most inviting for a settlement. Probably, on closer examination, the remains of a settlement might be found in the plain on the right bank, where the elder-bushes give welcome shade to man and beast. I have no doubt that the banks of Alamo Creek and the surrounding country will yet yield many remains of former settlements, as also the banks of the Santa Maria River and its tributaries, where, besides the settlement of Wă-lĕ-kh̆e, which I explored, there are two others, known to the ever-roving *Vaqueros.*

With regard to the general character of the domestic utensils, arms, and ornaments which I found in examining about three hundred skeletons in the graves of Kĕs-mă-lī, Tĕ-mĕ-tĕ-tī, Nī-pŏ-mō, and Wă-lĕ-khĕ, they all resemble each other very closely, seeming to show that their possessors all belonged to the same tribe. First of all, the large cooking-pots attract attention. They consist of globular or pear-shaped bodies, hollowed out of magnesian mica. The circular opening, having a small and narrow rim, measures only five inches in diameter in a pot with a diameter of eighteen inches. Near the edge of the opening, this vessel is only a quarter of an inch thick, but its thickness increases in a very regular manner toward the bottom, where it measures about one and a quarter inches. Made of the same material, I found other pots of a different shape, namely, very wide across the opening, and narrowing toward the bottom. With these I have also now in my possession many different sizes of sandstone mortars, of a general semiglobular shape, varying from three inches in diameter and one inch and a half in height to sixteen inches in diameter and thirteen inches in height, all external measurements, with pestles of the same material to correspond. There were, further, quite an assortment of cups, measuring from one and a quarter to six inches in diameter, neatly worked out of serpentine, and polished. The smallest of these was inclosed, as in a doubly-covered dish, by three shells, and contained paint, traces of which, by the way, were found in all these cups, from which we may suppose that they were not used for holding food.

Neither spoons nor knives were found in these graves. I got, however, three beautiful serpentine pipes, shaped like cigar-holders, much stronger than, but similar in shape to, those found in Oregon. Not many weapons were picked up here, only a few arrow and spear heads; these, however, were mostly of exquisite workmanship. A spear-head of obsidian, five and a half inches long, was the only object I found of this material; another lance-point of chalcedony, nine and a half inches long and one and a quarter inches wide, was beautifully shaped and carefully made.

A remarkable object is a bronze cup which was found at Tĕ-mĕ-tĕ-tī. It was filled with red paint, and contained also the pretty paint-cup inclosed in the three shells mentioned before. I also found in the same grave, a Spanish coin of the last century, and a bronze buckle, which latter was lost. The bronze cup, the coin, and a pot of burnt, coarse, sandy clay which was found at Nī-pŏ-mō, and also a few remains of corroded iron knives, found in the three graves, tell us of the last days of the existence of these people at a time when they evidently had held intercourse with the advancing missionaries, who, almost everywhere in America, were the pioneers of civilization.

Fig. 6.



Cave forming 90° with the two Birds.

Most of the objects were found perfect; and those which were not, had been broken by the pressure and shifting of the soil, as could easily be seen from their position. It is, therefore, certain that the bulk of the property buried with a person was not purposely broken nor destroyed, the same thing being true of my investigations in Oregon. I even found mortars and pestles which had been repaired and cemented with asphaltum. The richer occupants of the graves had shell and glass beads in great numbers, sickle-shaped ornaments of the *abalone* (*haliotis*) shell, and an ornament resembling *dentalium*, but made of a large clam-shell, strewed about their heads.

During my explorations I also diligently searched for caves which might have been inhabited and from which important information might have been obtained. But in these investigations I did not meet with much success, partly because I had not the time necessary at my disposal, for scarcely had I got to a place where they existed, when my duties demanded my attention and obliged me to give up the exploration. I could, therefore, only designate on my map the place which I might, with some degree of certainty, suppose to be a formerly-inhabited cave, so as to facilitate later investigations. Once I was obliged to suspend work at Point Sal for a whole week on account of thick fog. I had time, however, to search in the gorges and rocks, hoping to find ethnological objects. I discovered and opened at that time the graves of Kĕs-mă-lĭ, and not far off the cave, (Figs. 4 and 6.) But I was rather disappointed, when, after clambering through and over almost inaccessible places, I reached the cave, and found that it was only eight by four feet wide and eight feet high; and that there were in it only one pestle, with many oyster-shells, bones, and teeth. The floor was formed of stratified brown ash-like soil, in which were the above-mentioned objects. The circular entrance to the cave measured three feet in diameter. On the right-hand side of the entrance was a niche which had evidently been worked out of the hard but cracked sandstone, and was large enough for one person to sit comfortably therein. Toward the back part, the cave has also been worked out, so that a person might lie down stretched out; that is, I found that I could comfortably occupy these positions, although I am seventy-three inches in height. The whole cave, it appears to me, has been artificially made with a chisel. I did not examine the articles which it contained very closely, and must, therefore, refer to the collection itself. For the same reason, I have not said much about all the other objects of the collection, but refer for more particulars to the following catalogue and to the collection itself.

CATALOGUE OF IMPLEMENTS FOUND IN THE DIFFERENT GRAVES.

1. Cup for preparing paints, together with an egg-shaped grinder, No. 42. *Kĕs-mă-lī.*
2. Mortar for preparing paints; found with red paint in bronze vessel. *Tĕ-mĕ-tĕ-ti.*
3. Mortar, soft gray sandstone. Nī-pō-mō.
4. Mortar, hard gray sandstone. Nī-pŏ-mō.
5. Mortar, soft gray sandstone. Nī-pō-mō.
6. Paint-cup, dark stone, was found, together with the pipe, No. 46. N.*

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* N = Nī-pŏ-mō; K, Kĕs-mă-lī; T = Tĕ-mĕ-tĕ-tī; W = Wă-lĕ-khĕ-

7. Mortar, sandstone, roughly made. K.
8. Mortar, perfect. W.
9. Mortar. N.
10. Cup made of talco-slate. N.
11. Mortar, from graves at the mouth of San Luis Obispo Creek. (See map A.)
12. Mortar. N.
13. Mortar. N.
14. Mortar. N.
15. Mortar. T.
16. Mortar. N.
17. Mortar. K.
18. Mortar, repaired with asphaltum. W.
19–22. Mortar-halves, as found protecting skulls, (mostly of females,) N, K, and T.
23. Pot of magnesian-mica, pear-shaped. W.
24. Pot of magnesian-mica, wide opening. W.
25. Pot of magnesian-mica, globular. N.
26. Pot of magnesian-mica, globular. N.
27. Pot of magnesian-mica, globular. T.
28. Pestle, sandstone. N.
29. Pestle, sandstone. N.
30. Pestle, sandstone. N.
31. Pestle, well worked, found in cave at Point Sal.
32. Pestle, fragment. N.
33. Pestle. N.
34. Pestle. N.
35. Pestle, fragment.
36. Pestle, repaired with asphaltum. T.
37. Pestle. W.
38. Pestle. N.
39. Doubtful, at the shell-heaps. Point Sal.
40. Flesher, (dressing skins.) Point Sal.
41. Whetstone. K.
42. Egg-shaped pestle, (to cup No. 1.) K.
43. Egg-shaped pestle. K.
44, 45. Arrow-shaft polisher. N.
46. Pipe. N.
47. Pipe. N.
48. Pipe. N.
49. Amulet, (serpentine.) K.
50. Fossil, vertebra of (?) K.
51. Pot of burnt clay. N.
52. Cup of talco-slate. N.
53. Bronze cup. T.
54–66. Skulls. K.

Skull No. 57 supposed to be of a white man, and was found, with the rest of the bones, among the rubbish of a shell-heap at *Point Sal.*

67–70. Skulls. N.
71. Skulls. W.
72. Bones. W.
73. Slab, of which the linings of graves, in most cases, consisted. N.
74. Shell-ornaments. N.
75. Teeth, shell-heaps. Point Sal.
76. Cup covered with three shells. T.
77. Glass beads. N.
78. Shell beads, (dentalium-like.) N.
79. Ornament. Point Sal.
80. Plate, (fragment.) N.
81. Plate. N.
82. Plate, (machine-drilled hole.) N.
83. Beads made of shells. K.
84. Bone(-bow ?) shell-heap. Point Sal.
85. Hair, &c.
86. Bill of a bird, found in the mouth of a skeleton. N.
87. Red color, found in a pot.
88. Beads of serpentine and shell. N.
89. Mortar, (ornamental ?) N.
90. Rim of a bowl of serpentine. N.
91. Seed found in a pot. N.
92. Arrow-heads found with skull No. 105, on a temporary camping-ground, as remarked in the text.
93. Ear-ornaments. N.
94. Shell ornaments. K.
95. Seed found in a pot. N.
96. Abalone ornaments. N.
97. Abalone found in excavity of brains. N.
98. Crystals of quartz. N.
99. Shell ornaments, (dentalium-like.) N.
100. Cave results.
101. Bead of shell, finely finished and carved. K.
102. Shell ornaments.
103. Wall of grave. K.
104. Skull, animal, found on shell-heap. Point Sal.
105. Skull found on temporary camping-ground, as mentioned in text, with arrow-heads, No. 92.
106. Spear-heads and arrow-points. N.
107, 108. Lance-heads.
109. Knives, as found especially on temporary camping-grounds.
110. Ornaments of serpentine. N.
111. Stone blade. N.

112. Pestle, on shell-heaps. Point Sal.
113. Black paint, (?) found in pots, and often strewn about the skulls.
114. Knives, arrow-heads, &c., as found on surface near mouth of Santa Maria River and other places, with indications of a formerly-permanent camp.
115. Red paint.
116. Coin.

REMARK.—The name of the grave was attached to the article when exhumed, and the place described when it was found on the surface.

ACCOUNT OF THE BURIAL OF AN INDIAN SQUAW, SAN BERNARDINO COUNTY, CALIFORNIA, MAY, 1874.

By W. M. KING.

The body, cleanly washed, was dressed in its best clothing. Outside of the clothing, and confining it to the body, was a bandage, apparently a sheet, torn in half. The feet were covered and bound together, the arms confined to the side, and the face covered by a bandage. The body thus prepared was laid upon the ground, while the men of the party dug the grave. While the grave was being dug, an old squaw danced slowly once round the body, singing in a wailing tone, then seated herself at its head, and continued her singing and wailing, sometimes breaking off and addressing the corpse, at the same time patting its head with her hand. The grave being completed, the body was lowered into it, its head toward the south. The personal effects of the deceased were placed beside her. These consisted of a bundle of bed-clothing, several small bundles of calico, various tin cups and pans, a table-knife and spoon, a frying-pan, and, lastly, a small quantity of live ashes was thrown in and the grave filled up. A fire was then lighted on top of the grave, the squaw who acted as chief mourner gathering the sticks. She also threw on the pile a number of platter-shaped dishes or baskets of plaited grass, which were burned. When the fire had burned itself out, the squaw above mentioned advanced and broke an *oya*, or water-cooler, on the grave, by violently dashing it on the ground. The party then dispersed.

A day or two afterward the house in which the woman died was purposely burned. The dishes and *oya* that were destroyed showed signs of long use, but were still perfectly serviceable. During the burial, no signs of emotion were shown by any of the party, either men or women, except by the squaw alluded to.

ANCIENT MOUNDS OF MERCER COUNTY, ILLINOIS.

By Tyler McWhorter, of Aledo, Ill.

It may be approximately estimated that there are more than a thousand mounds in this county, yet persons who have not directed their attention to the subject would not suppose half that number to exist. These mounds are generally not such as to attract very special observation, not being of the larger size, the principal groups are very much flattened down by time, and seem to relate to a more remote antiquity than such as are more conspicuous.

These mounds are all located in the portion of the county bordering on the Mississippi River. This fact, that the western mounds are universally found on lands adjoining the rivers, suggests the inference that the race who erected them procured their subsistence mainly from the water, or that the bottom-lands of the rivers constituted their principal hunting-grounds.

The largest group of mounds in this county is found in Eliza Township (township 15 north, range 5 west,) on high timbered land, about a mile or so back of the Mississippi bluffs. In this group may be found over two hundred mounds within the distance of a mile. This group seems to be of great antiquity, and is quite flattened down by the elements—only rising a few feet above the general level. Probably successive forests have grown and passed away since they were constructed. Only a few have been opened, and these revealed only beds of ashes and a few stones. But what seems strange, traces of ashes are often found mixed with the earth of which the mounds are composed.

In the immediate vicinity are also found obscure lines of old embankments that seem to relate to the same age as the mounds.

On the bottom-lands of the Mississippi, not far from the foot of the bluff, in the same township, are found a few mounds of a very distinct character. They rise up with quite an abrupt elevation, and are manifestly of a much more recent date. Presuming that the more ancient mounds, in the high timbered lands, at some former time had the same abrupt elevation as these, it manifestly must have required many years to reduce them by atmospheric action to their present flattened condition. From this apparent difference in the antiquity of the mounds, it is evident that the race or races who erected them continued to inhabit this country for a considerable length of time. In these more recent mounds human bones have been found with the usual accompaniment of ashes and stones. Also, in one of them a stick of wood was found, about eight inches in diameter, in a horizontal situation, a little to one side of the center of the mound; it was in quite a sound condition.

As no depressions of ground are ever found in the immediate vicinity of mounds, it is often difficult to conjecture where the earth was obtained of which they were constructed; but there is a circumstance in connection with the more recent mounds that seems to have a bearing on this question. There is a considerable space of ground, nearly two hundred yards distant, where it seems manifest that the upper stratum of the surface soil has been carried away. A uniform upper stratum of soil is common to a large extent in this bottom-land, but in this one spot this layer is gone. It seems, therefore, probable that the earth of which these mounds were constructed was all carried from this place. An approximate estimate of the cubical quantity of the superficial earth removed from this depression, corresponds closely to what seems to have been the original quantity in the recent mounds. It is difficult to understand what motive could induce human beings to impose on themselves such a task as to carry such an amount of earth two hundred yards. But if the amount of material necessary to erect these mounds had been taken from any immediate piece of ground on this uniform surface, some depressions would have remained as evidence of it. But at the distance of two hundred yards we find this depression, which is nearly as hard to account for by any natural process as it would be to explain the mounds themselves by natural agencies.

There is another quite extensive range of mounds in the same township, on grounds bordering a stream of water called Eliza Creek. So far as I have observed, this group seems to relate to a very ancient period of time. Few of the mounds, to my knowledge, have been opened. I am told that traces of ashes have been found in them, and, in some of them, human remains in a much decayed condition.

Another very extensive range of mounds is located in the township of New Boston, which is the next township south of Eliza. These are on the south side of the Edwards River, where this stream winds its course across the higher bottom-lands of the Mississippi. The ground of these mounds has been under cultivation for many years, hence but obscure traces of them now remain. Their location was on the open prairie, about a half-mile from the timber-grounds bordering the Edwards.

Broken pottery, pipes, and some implements were found by early settlers in the vicinity of these structures; but I have been unable to learn with certainty whether these were disinterred from the mounds themselves.

There is, however, one circumstance in connection with this group of earthworks that should not be passed unnoticed. Between them and the Edwards is a long range of depressions in the ground. This range of depressions runs nearly parallel to the range of mounds, and is about forty rods distant. The size of these hollows seems to correspond very nearly with the size of the adjacent mounds. The conjecture seems unavoidable that from each of these depressions sufficient earth was carried to construct a single mound. These excavations have no raised borders to indicate that the earth was merely thrown out; they indicate that so much earth has been really *taken away;* and, further, I learn that the number of these depressions corresponds quite nearly with the number of the adjacent mounds, being about one hundred and fifty.

Another considerable group of mounds is located in the same township of New Boston, several miles farther up the Edwards, on high terrace-ground, about a half-mile from the stream. This group was entirely away from timber, the situation being formerly covered with grass. For many years the ruthless plow has been leveling down these ancient memorials, and fields of grain have long waved over the ashes of a by-gone race.

On the south side of Pope Creek, near where the valley of this stream cuts through the Mississippi Bluffs, is quite an extensive group of mounds. Some of them are high up on the brow of the bluffs. Nothing that I can learn distinguishes this group from others already spoken of. Human bones have been found in some of them.

The next, and last, group of mounds to which we would call attention is about twelve miles from the Mississippi River, being the most remote from that river of any group in the country. It is situated near the north side of the township of Millersburgh, on the high-timbered division between the Edwards River and Camp Creek. Ashes and some much-decayed relics of human skeletons have been found in the few that have been opened. Some traces of ashes were found in the earth above the human remains.

I have made diligent inquiry of all the oldest settlers, and am unable to learn that any mounds are to be found in the eastern portion of the county, except that two or three isolated ones, which are reported to be far up the Edwards. These I have never seen.

SHELL-HEAPS.—Before closing this paper, it may be proper to state that formerly very large shell-heaps existed on the high, sandy bank of the Mississippi, immediately below New Boston. But it seems more probable that these heaps of kitchen-refuse relate to the subsequent Indian race, and not to the mound-builders. Though these shell-heaps are in a considerable state of decay, enough remains of them to show that the shells belong to the present species of our rivers. Broken pottery is found about these heaps, and collections of burned stones, indicating old camp-fires; also, abundance of flint-chips, and some broken arrows, are found here, to indicate that flint-implements have been manufactured. A careful inspection of these flint-chips leads to the conclusion that the flint of which these implements were made was obtained from what is called the "chert-bands" of the Burlington limestone. This formation crops out along the Mississippi, about forty miles below this place. Probably the material for the manufacture of these implements was brought up the river in canoes.

ANTIQUITIES OF WHITESIDE COUNTY, ILLINOIS.

By W. H. Pratt, of Davenport, Iowa.

Corresponding Secretary Davenport Academy Natural Sciences, Davenport, Iowa.

On the eastern bank of the Mississippi River, in Whiteside County, Illinois, is situated the village of Albany. Over the bluffs in the neighborhood is a growth of young oak trees, the largest of which are ten or twelve inches in diameter. On the bluff and the slope toward the river, about a mile south or southwest of the village, scattered irregularly over an area of about one-fourth by three-fourths of a mile, are fifty-one ancient mounds, the positions and dimensions of which I have approximately determined, having spent several days in August of this year, 1873, in the exploration in the interest of the Davenport Academy of Natural Sciences.

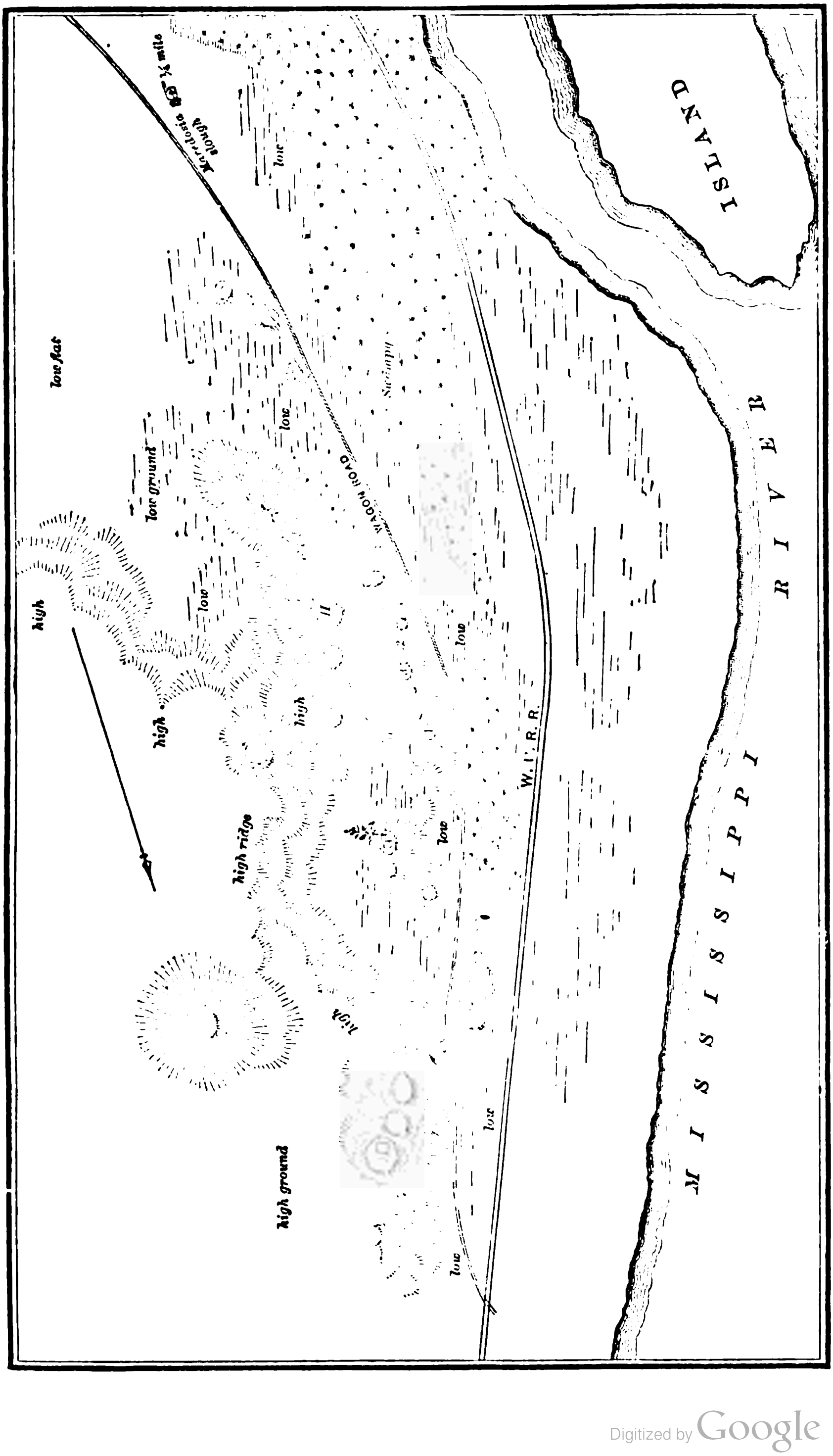
A general view of the whole is represented in the accompanying plan, (Fig. 1.)

The land is owned by Mr. Samuel Rosenkranz, of Albany, who kindly allows the exploration and excavation of the mounds without restriction, except the reservation of a few of the most prominent. A few other mounds are said to exist not far distant to the northeast, but I have not seen them. It is also stated that two or three were removed some years since in making the grade of the Western Union Railroad, which passes close by the mounds, between them and the river. Over the area above mentioned the young timber has been mostly cut off, and on the higher portions evidently very few trees have ever existed. The soil is almost entirely sand. The high land or bluff terminates abruptly to the southward in a bold, narrow point.

A position on one of the highest mounds, some of which are situated on this point, commands one of the broadest views to be found in the whole Mississippi Valley, with a sweep of more than half a circle, including the river and valley, and islands to the north and west and southwest; and to the south and southeast the "Dosia," as it is commonly called, or "Maredosia Slough," or, as it was originally named, the "*Marais d'Ogée*," an ancient channel of many miles in extent, connecting the Rock River with the Mississippi. In this the current flows in either direction from the higher toward the lower of the two rivers at different times. The "slough" is a broad marsh, nearly dry during a dry season, and is believed to have been once the channel of a part of the Mississippi, which divided at this point, and re-united at the present mouth of Rock River, forty miles below. The location is one of rare beauty, and has doubtless been for ages, as it is now, a favorite resort of hunters. The high point above mentioned is a narrow and rather abrupt sand-ridge, formed doubtless by the action of the current when the Father of Waters occupied the entire breadth of the valley.

There is nothing in the relative position of the tumuli, as will be

Fig. 1.


Marrdosia slough ☞ ¼ mile
ISLAND
low
low flat
Swampy
low
low ground
WAGON ROAD
high
low
II
low
high
high
high ridge
low
W. I. R. R.
MISSISSIPPI RIVER
high
low
high ground
low

readily seen by reference to the diagram, to indicate any arrangement or design whatever, except to construct them where it could be done with least labor, by taking advantage of the ridges and slight elevations of loose and sandy soil. The structures vary in height from two to twelve feet, the diameter being five or six times the height. They are usually circular, only four or five being elliptical, the length of these about double the breadth, and the longer diameter being parallel with the river. The outline of surface is such as would naturally result from a rounded heap of sand or loose earth exposed for ages to the action of the elements, the surface being protected by such grasses, plants, bushes, or trees as the soil would produce. The exact height and diameter are consequently difficult to determine, but it would appear that they had originally been from four to fifteen feet in height and perhaps four times those measures in diameter.

All of the largest mounds and several of the smaller are upon the high ground, from one hundred and twenty to one hundred and fifty feet above the river. The rest are on the slope between it and the river. I selected for examination one of several similar mounds, which were situated in a row parallel with the river, and but a few rods northwest of the sandy ridge, at some fifty feet lower level, and on ground sloping gently toward the Mississippi, which is distant about one-fourth of a mile. This mound is marked 1 on the plan. It was about four feet high and twenty-five in diameter. On the top was the stump of an oak tree, five inches in diameter. This mound is composed, as are the most of those which have been opened, of a loose fine sand, with here and there a stone of two or three pounds' weight or more, of the Niagara limestone and the sandstone common in this region, many of them evidently having been subjected to the action of fire before they were placed there. No floor, wall, or internal structure of any kind was found, and the same is the case in almost all instances in this district.

Making an excavation from one side and toward the middle, on reaching a depth of six feet from the top, a quantity of human bones was discovered lying about in the center of the mound. Seven adult and one child's skulls were exhumed, the latter falling in pieces as soon as it was removed. The adult skulls were more or less crushed and distorted, and some portions entirely decayed; two of them, however, were secured in tolerably good condition, one containing thirty-two sound teeth, the other wanting but two or three. Many teeth were found with fragments of decayed jaw-bones, and it is very evident that, whatever the troubles and trials to which their possessors were subject, that plague of modern times, the tooth-ache, was one from which they were pretty much exempt.

The crania have apparently been subjected in life to no artificial distortion nor compression, except, possibly, some flattening of the occipital region, such as is said to be produced by the position and manner in which some tribes confine the infant to a cradle-board. This seems the more probable, as it is observed that the children's skulls found here exhibit the same peculiarity in a more marked degree; the adults having probably partially outgrown its effect. The heavy, superciliary ridge, retreating forehead, and protruding and very wide jaws, and great bi-mastoidal diameter, as compared with the bi-parietal, are indicative of physical rather than of mental or moral capacity.

The accompanying description, with table of measurements by Dr. Farquharson, will abundantly show such prevailing peculiarities as fully identify them as skulls of genuine "mound-builders."

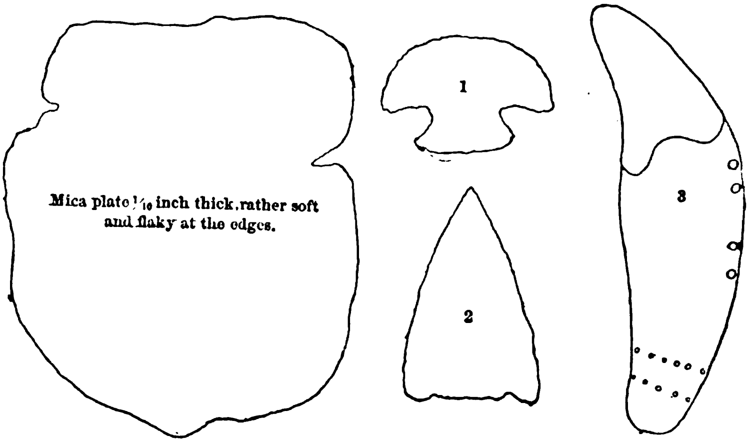
As portions of all parts of the skeleton are found, it would appear that the whole of each has been deposited there, though thrown in rather "promiscuously." The heads were nearly all lying in the same direction, southward, in some cases in contact with each other, and the other parts so intermingled and decomposed as to make it impossible to trace any one skeleton, or to determine to which one an individual bone belonged. Many of the small bones and the softer portions of the larger ones are entirely gone. The best-preserved skeleton, No. 3, was lying stretched out in a horizontal position, with the face upward, and was a few inches above the rest, and, of those which were piled in together, one was lying on its right side.

The sand below, above, and around the bones presents the same uniform appearance, from a yellowish-gray to a reddish-brown color, except that that immediately about them is usually a little darker; and occasional irregular and uneven streaks of rather darker sand are found, as if some loads or parcels of the earth of which the heap is formed had been partly of a dirtier surface-soil, and had been thrown scattering over the surface and then covered with cleaner sand. A few of the most southern mounds, where the earth is gravelly, are composed of sand and gravel, showing that, as in the other cases, they are built of the material nearest at hand.

It would appear that the process of interment had been a very simple one, viz, selecting a spot where the earth was loose, sandy, and easily removed; scraping away the earth to the depth of a foot or two, then carelessly depositing a few bodies, or rather perhaps a few skeletons, collected possibly from elevated scaffolds, trees, or other positions where the bodies had been previously placed; then replacing the sand which had been removed, and adding enough from the surrounding surface to raise a heap of such dimensions as the inclination to manual labor and the respect for the deceased would prompt. The position of the skeletons is a pretty certain indication that the bodies were not interred one at a time, as that could not have been done without in each instance entirely uncovering those previously buried, the skulls being in some cases in contact with each other.

In this mound no relics, such as weapons or implements, were found, except a very small fragment of pottery in the earth, about a foot from the surface, and an arrow-head of very peculiar form, which was lying among the bones.

Fig. 2.


Mica plate 1/10 inch thick, rather soft and flaky at the edges.
1
2
3

In November, several members of the academy visited the locality for the purpose of further exploration. On this occasion three more mounds were opened under the direction of Mr. A. S. Tiffany, who spent the previous day in making preparatory excavations, so that considerable search could be made in a few hours. He opened the mounds marked 2, 3, and 4 on the plan. Nos. 2 and 3 were similar in all respects to No. 1.

In No. 2 nothing was found except a few bones, the remains probably of only two or three bodies, very much decomposed, and a few teeth, of which only the crown remained. In No. 3, at the depth of six feet from the surface, were found the skeletons of four adults, lying stretched out, face upward, two with heads toward the east and two toward the west. The four occupied a space of about four feet in width. Two children had also been buried there, perhaps at a later date, but their position could not be well ascertained. One of the skulls (skull No. 5) from this mound was obtained in a very perfect condition, except that most of the teeth are wanting. In this mound were discovered, lying immediately above the skeletons, several relics of considerable interest, viz, a plate of mica, about three by four inches and one-eighth of an inch thick, with several notches in the edges; a small lump of galena, surface much carbonized, and the corners worn, apparently by handling; a dove-colored flint arrow-head, very finely wrought, sharp, and smooth, (No. 2;) several flakes of white flint; and a strangely-formed bone implement, charm, nasal ornament, or whatever it may have been, (No. 3.) It is a fragment of a marrow bone, four and a half inches long, and one and a quarter wide at the middle, tapering nearly to a point at the ends, one of which is more pointed than the other, and much curved edgewise. Close to the edge, at the convex side, at the widest part of the bone, are four holes, about one-eighth of an inch in diameter, but differing slightly. They have the appearance of having been drilled with a tool not much, if at all, tapering in form, and with a square cutting-edge, which was not worked entirely through, as there remains in each hole, on the inner side, a little edge which is not quite cut away. Across the bone, near the larger end, are two rows of holes—five and six in a row—one-tenth of an inch or less in depth, drilled with some round-pointed instrument. One curved line is cut across, as shown in the figure. The article seems much worn by handling. What was its use, we can scarcely conjecture; and some Indians (Sacs and Foxes) to whom it has been shown, can give no clue.

The mound numbered 5 on the plan is like the others in material and structure, except that it is much larger, being about sixty feet long, thirty feet wide, and seven feet high. In this mound an excavation was made in the middle, only about five feet square, which we hope to work out more thoroughly at another time.

About two feet below the surface was found a much-decayed fragment of the "shin-bone" of some mammal, possibly the bison; and a little deeper, two fragments of pottery, parts, apparently, of the same vessel, and bearing impressions on the outer surface of some kind of woven or matted fabric. At the depth of nine feet was discovered a large and remarkably well-preserved skeleton, almost entire, wanting only a few of the very small bones, fingers, and toes, and the more perishable portions of a few of the larger ones.

The skull (No. 6) is in tolerably good condition, and contains the entire set of sound teeth. The pelvis was obtained almost perfect, which was the case in no other instance. This skeleton, also, was lying at full length, with the face upward and head to the east, in the direction of the transverse diameter of the mound.

Immediately south of this was another skeleton, and over these some others, all in a less perfect state of preservation than the one first mentioned, and the bones somewhat intermingled with it and each other. One was that of a child of ten or twelve years. Close to the skeletons, and immediately north of the first named, were a number of stones lying, whether by accident or design, in a very irregular row, probably accidental. Among the human bones was a piece of the lower jaw of the deer or elk, containing four molars, all well preserved.

So far as our observations go no metallic articles of any kind are found there, though it is reported that some years since a copper knife was taken from one of the mounds.

Many of the mounds have been opened and partially explored by citizens and visitors in search of curiosities, and of late such visits are more frequent than ever. That these structures were merely burial-places and nothing more, is evident from the fact that, ordinarily, there is in them no trace of floor or roof, and no charred wood or bones, or other indications of fire.

Some estimate of the original maximum height of these tumuli may be formed from the observation that sandy earth, such as that of which they are composed, will not remain in position on a slope of more than 40° from the horizontal; they could not, therefore, have been higher, even if raised to a point at the apex, than two-fifths of the width at the base; and the very first rain or wind would reduce them considerably. As they are now, they would probably remain, with contour unchanged by the action of the elements, for a thousand years to come.

In one of the largest mounds, (W,) about twelve feet high, and standing on the highest ground, opened some years since, was discovered an inclosure of "dry wall," some ten feet square, containing a number of skeletons supposed to have been buried in a sitting posture, with no indication of any covering or floor having ever been there, save the earth of which the whole mound was composed. A portion of this wall, which still remained exposed, we carefully removed for examination, and found it to be built of the fossiliferous limestone common in the neighborhood, brought probably from near the river-bank, a quarter of a mile distant and a hundred feet lower; laid up with tolerable evenness on the inner side. It was about three feet high, two feet thick at the top, and three feet at the base, piled up loosely, the lower stones broad and flat, rather heavier than one man could well carry, and lying on the clean, yellowish sand. Some of the stones had been burned red previously to being placed in position. This inclosure was entirely at one side of the center of the mound, and nothing of interest was found in the other part.

This region has long been occupied by the tribe of Indians known as the Sacs and Foxes, who came from the region of the Saint Lawrence over two hundred years ago, and remained until about the period of the Black Hawk war, about 1832.

George L. Davenport, esq., of this city, who was born on the island of Rock Island, in 1817, and was the first white child born in this section of the country, and who has been intimately acquainted with the Indians for over fifty years, and speaks their language, informs us that the natives positively had no knowledge of these structures, and paid no attention whatever to them. They had a village or town in the immediate neighborhood of the mounds, though their principal town was near the site of the present city of Rock Island.

It is, therefore, certain that the mounds presented much the same appearance many years ago as now, and that these Indians neither constructed nor used them.

No evidences of "intrusive burials" have, in any instance, been discovered, and without doubt the mounds have been as at present, and entirely undisturbed, for many centuries, until opened by recent explorers.

We inclose herewith a diagram of the group of mounds, also drawings of the relics exhumed, and a series of photographs of all the well-preserved crania.

We also have the pleasure of presenting an exhaustive report upon the crania, by Dr. R. J. Farquharson, a member of the Davenport Academy of Natural Sciences, including measurements, analyses, and careful comparison with skulls of other races of men, and with other well-authenticated mound-builders' skulls.

We also inclose Mr. A. S. Tiffany's description of the locality, on Rock Island, where he discovered the skull which is represented by photograph No. 8.

A STUDY OF SKULLS AND LONG BONES FROM MOUNDS NEAR ALBANY, ILL.

By R. J. Farquharson, M. D., of Davenport, Iowa.

This lot of bones was obtained from mounds near Albany, Ill., by the Davenport Academy of Sciences. The topography, &c., of these mounds is given in the preceding paper by Mr. Pratt, who conducted the explorations.

In the first place, an attempt was made by a rude analysis to arrive at the probable age of these bones. A small part of the middle portion of one of the long bones was incinerated, with the following result: Weight before incineration, thirty-eight grains; afterward, thirty grains; loss, eight grains; equal to 20 per cent.

	Mineral matter.	Animal matter.
Fresh bone, (dry,) Berzelius	67	33
Mound-builder's bone	79	21
	12	12

Now, as the lightness, or diminished specific gravity of these bones, precludes the idea of an increase of the mineral matter, and also as we know that, in certain conditions of soil, an actual loss of mineral matter takes place, we may safely infer that a considerable loss of animal matter has here taken place; a loss even greater than what the above figures would seem to indicate.

But, unfortunately, these data will not afford even an approximate estimate as to the time since these bones were buried.

"In an old Roman frontal bone dug up from Pompeii, Dr. Davy found 35.5 animal parts, and 64.5 earthy; and in the tooth of the mammoth 30.5 animal, and 69.5 earthy." (Todd and Bowman's Anatomy, vol. 1, p. 105.)

Orfila, in his Exhumations Juridiques, (vol. 1, p. 350,) states that bones buried in the cemetery of the Innocents, Paris, over six hundred years, yielded, in analysis, 27 per cent. of gelatin and 10 per cent. of fat; while fresh ones yielded only 30 per cent. of gelatin, showing only a slight alteration. On the other hand, bones exhumed from the church-yard of Ste. Geneviève, Paris, after a burial of over seven hundred years, showed marked alteration, which he describes as follows: Very brittle, of a purplish color; remarkable both for the absence of animal matter and for the presence of the acid phosphate of lime. Unfortunately, no analysis of these changed bones is given.

TABLE No. 1.—The plan of this table is taken from Foster's work on the prehistoric races of the United States, and the letters at the heads of the columns refer to the same measurements. Four other columns are, however, added, the first giving the capacities in cubic inches; an important point omitted by Foster, probably from the fragmentary nature of the skulls in his possession. The second and third added columns give the distance of the occipital protuberance from the posterior margin of the *foramen magnum* and the ratio of this distance to the long diameter of the skull. This is an important characteristic of the mound-builder race, according to Dr. Wyman.

The fourth and last column gives the major and minor axes of the *foramen magnum* in millimeters.

TABLE No. 1.

Race of skull.	Condition.	*A	*B	*C	*D	*E	*F		Capacity in cubic inches.	Distance of occ. prot. from for. mag. in inches.	Ratio of distance to long diameter.	Size of for. mag. in millimeters.
							B′, (mastoid.)	B′, (parietal.)				
I. Mound-builder, 1	Imperfect	21.5	12	10	4.1	8	5	4.8	72.75	......	.....	.....
II. Mound-builder, 2	Perfect ...	19	12	10	4.125	6.5	5.5	5.1	72.75	2	0.307	39 × 28
III. Mound-builder, 3	... do ...	19.5	11.5	9	3.5	6.6	5.5	5.1	62.35	2.3	0.348	39 × 32
IV. Mound-builder, 4	Imperfect	19	11	8	3.5	6	6	5.6	......	.....		.....
V. Mound-builder, 5	Perfect ..	20	11.5	9.5	3.9	6.6	5.6	5	81.40	2.4	0.363	36 × 32
VI. Mound-builder, 6	Imperfect	20	12.5	....	4.5	6.5	..	6	......	......	......	......
VII Sioux 1..........	Perfect ...	20.5	12.5	10	3.5	7.1	5.1	5.1	80.53	1.9	0.267	42 × 35
VIII. Sioux 2..........	....do	21	12	10.5	4	7.125	5.5	5.1	76.20	2.2	0.310	40 × 31
IX. Sioux 3..........	....do	20	11.5	9	3	7	4.8	5.125	76.20	2.1	0.300	38 × 35
X. Average mound-builder.....		19.83	11.7	9.3	3.93	6.7	5.6	5.1	72.31	2.2	0.328	*.1122
XI. Average Sioux..............		20.50	12	9.8	3.50	7.03	5.1	5.1	77.64	2.0	0.284	*.1257

* Square millimeters.

REMARKS.

I. Capacity approximate, from imperfection. Ratio of short and long diameters, 0.60 to 0.625.
II. Ratio of short and long diameters, 0.846 to 0.784
III. Skull, thick and heavy, from former disease. Ratio of short and long diameters, 0.833 to 0.772.
IV. Ratio of short and long diameters, 1 to 0.933.
V. Aged—molars all gone and alveoli absorbed. Ratio of short and long diameters, 0.848 to 0.757.
VI. Ratio of short and long diameters, 0.923 to 0.923.
VII. Ratio of short and long diameters, 0.718 to 0.718.
VIII. Ratio of short and long diameters, 0.771 to 0.715.
IX. Ratio of short and long diameters, 0.685 to 0.732.
X. Ratio of short and long diameters, 0.836 to 0.761.
XI. Ratio of short and long diameters, 0.725 to 0.725.

*A. The horizontal circumference in the plane of a line joining the glabella with the occipital protuberance.
*B The longitudinal arc from the nasal depression along the middle line of the skull to the occipital tuberosity.
*C. From the level of the glabello-occipital line on each side, across the middle of the sagittal suture to the same point on the opposite side.
*D. The vertical height from the glabello-occipital line.
*E. The extreme longitudinal measurement.
*F. The extreme transverse measurement.

TABLE No. 2.—In this table an attempt is made (by means of another table of the comparative lengths of the various long bones in a series of skeletons, given in Orfila's Exhumations Juridiques) to arrive at some idea of the stature of the mound-builders, but the conclusions are very imperfect, perhaps necessarily so. Enough was learned, however, to safely warrant the conclusion that none of the bones examined belonged to an individual much, if any, higher than six feet, thus doing away with the assumption, made by some persons at the time of the exhumation, that some of the mound-builders were giants.

TABLE No. 2.—*Stature estimated from length of bones.*

Race.	Bone.	Length in centimeters.	Major axis in millimeters.	Minor axis in millimeters.	Estimated length of skeleton in meters.	Height of man in feet and inches.(1)	Remarks.
Mound-builder, 1.	Femur	46	30	29	1. 77	5. 11	Neck of femur long and not oblique.
Mound-builder, 2.	do	45½	30	28	1. 71	5. 09	
Sioux	do	45	33	29	1. 67	5. 07	Belongs to Sioux skull, No. 2.
Mound-builder, 1.	Tibia	32	33	22	1. 49	5. 00	
Mound-builder 2.	do	....	(2) 38	23	....	....	A fragment, upper half.
Sioux	do	38	36	28	1. 69	5. 08	Belongs to Sioux skull, No. 2.
Mound-builder, 1.	Humerus	33	....	(3)	1. 80	6. 00	
Mound-builder, 2.	do	34	....	....	1. 83	6. 02	
Mound-builder, 3.	do	33	....	(3)	1. 80	6. 00	
Mound-builder, 4.	do	31	....	....	1. 67	5. 07	
Sioux	do	33	....	(3)	1. 80	6. 00	Belongs to Sioux skull, No. 2.

1. The total length of the body is made out by adding two inches to that of the skeleton.

2. These diameters, taken near the middle of the length of the tibia, and at its most prominent part, show its flatness and the comparative sharpness of the shin-bones.

3. From an average of five skeletons in the table having a humerus measuring 33 centimeters. Here it may be remarked that in the French table there is a greater disparity in the height of the skeleton, in regard to the humerus, than either to the femur or tibia, one skeleton of 1.86 meters having a humerus of only 33 centimeters.

The skulls and long bones of the modern Indians used in the comparative measurements in these tables, were those of male Sioux Indians from Minnesota, who died in this vicinity, while in captivity on account of their complicity with the massacre in that State, so that there can be no doubt of their identity.

It only remains to remark, in conclusion, that an unusual number of perfect sets of teeth were found in the mounds examined. These teeth are invariably without any signs of decay, of almost flinty hardness, and very much worn away, apparently from the attrition of very hard particles in the food, probably the siliceous outer coats of some kind of grain or seeds.

THE SHELL-BED SKULL.

By A. S. TIFFANY, OF DAVENPORT, IOWA.

On the Rock Island arsenal-grounds, near the western extremity of the island, there had been an excavation about three hundred feet long and eight feet deep. At a depth of three feet from the top there was a deposit of shells, mostly *unios*, but including *melantho subsolida*, and two or more species of *helix*. This shell-bed at this exposure varies from six to sixteen inches thick.

In this deposit the skull and bones belonging to one individual were found; all the covering was an aqueous sediment. Deposited with and above the shells are lime, gravel, and sand, the material becoming finer toward the top, the last foot being fine alluvium and vegetable-mold. The sedimentary lines were perfect and unbroken, and the excavation had made the means of observation all that could be desired.

It was visited by many members of our academy, and by Prof. Alexander Winchell, while some of the bones were in place; and all agree that the covering to this pre-historic man was put on by sedimentary deposit.

Accurate levelings prove the top of this deposit to be eighteen feet above the highest water known since Fort Armstrong was established on the island.

ANTIQUITIES OF NORTHERN OHIO.

By Geo. W. Hill, M. D., of Ashland, Ohio.

In the spring of 1872, Mr. S. W. Briggs, a farmer of Sullivan Township, Ashland County, while plowing an old "cat-swamp" or slough, came upon a bed or nest of Indian flint-implements about eighteen inches beneath the surface. His attention was arrested by a grating sound beneath the plow, and on examination found two or three peculiarly-shaped arrow-heads or flint cutting-points. Hastening to his house, he procured a shovel and mattock, and proceeded to unearth the deposit. On carefully removing the surrounding soil—rich black mold—he found a keg-like vessel of red-elm (*Ulmus rubra*) bark, about three-fourths of an inch in thickness, some ten or twelve in diameter, and about thirteen in height. The vessel was a section of the bark, which had been removed from the tree by cutting or notching around the body and then peeling it off. It would hold something over one peck. It was in a tolerable state of preservation. It contained two hundred and one flint-implements, neatly and symmetrically finished, and a number of fragments which had not been dressed. The bottom of the nest was about two feet below the surface. About four feet south of the vessel his plow struck a forked oak-stake, the double end being deep in the mold, and also another stake, of the same timber, about four feet east of the deposit, driven deeply into the loam. The lower ends of the stakes were over three feet deep, the parts above the water and ground having decayed were wanting. In digging down, the forks were found to be beneath the surface soil and quite sound. There was also a streak of yellow sand about ten inches wide, two or three deep, and eight or ten feet long, running in a northeastern direction from the deposit, which could have been plainly seen when the water stood over the slough. This sand is found on the banks of Black River, about one and a half miles distant. The slough was drained some ten years since, and has been once or twice superficially plowed. The sand-streak was evidently put there to mark the precise point of the deposit.

Sixty years ago, when the first of the pioneers began to settle in the central parts of Ashland County, the northern section was a favorite resort of the Delawares and Wyandots as a hunting-ground. About twenty-five rods southwest of the slough are the remains of an Indian village or camping-ground. Floors of broken bowlders and large pebbles were made by driving the pieces into the ground until a smooth surface was obtained. About one hundred rods in a northeastern direction from the deposit is another "cat-swamp" or slough, somewhat smaller than the first, which will probably, upon examination, be found to contain other deposits. A few rods east of this were also found two stone floors, constructed of the same materials and in the same manner as the other. They were twelve or fifteen feet in circuit each, and had to be dug up before the ground could be plowed. About one mile southeast of this ancient village was a salt-spring, which was a common resort for the Indians and wild animals. Many relics have been dug and plowed up in its vicinity, among which was a large pair of elk-horns. Above this, on the flat, near the head branch of Black River, were several extensive beaver-dams. They were visible for many years after the settlement of that region.

In 1755–'56, James Smith, when a captive among the Wyandots and Delawares, on his way to the Canesadooharie, in company with his adopted brother, Tontileaugo, passed this locality. He had traversed the Jerome Fork of Mohican to its source, about three miles from the head of the Canesadooharie, or Black River, and over the portage or divide between the streams running south to the Gulf of Mexico and north to Lake Erie. At that time there was a large Wyandot village near the falls, not a great distance from the present site of Elyria, in Lorain County. The Black River and its sources long furnished a hunting-resort for the Ohio tribes, and the locality where these implements were found was often a great encampment for the Indians.

There is a striking resemblance to each other in the implements found by Mr. Briggs. They are generally leaf or pear shaped. They are about three-eighths of an inch in thickness. The width of the largest is two and three-quarter inches, and its length three and one-quarter inches. The next largest is two and one-quarter inches wide, and four inches long, running to a sharp point. They are all quite sharp around the edge, and neatly and symmetrically chipped, and would answer for cutting-tools.

It is difficult to determine their use. They certainly were not used as arrow-heads, being destitute of nicks to attach them to the shaft. They are too small for agricultural instruments. They could not be used for preparing dug-out canoes, being sharp around their edges, and too fragile. They may have been used for skinning and cutting the flesh of animals. Possibly they were used in dressing deer-skins. The entire lot was new, and looked as if they had been finished just prior to the deposit. So far as my observation extends, no flints of similar character have been found on the surface in this part of Ohio.

The material out of which these instruments were constructed is found in abundance about eighty miles south of the Black River, and is known as the "Flint Ridge," in Licking County, and consists, after exposure, of a reddish, mottled flint, and, when fresh from the quarry, of a bluish, or nearly black, color. The reddish tint may have originated from their burial beneath the bog or marsh water. When a boy, some thirty-five years since, I resided a short distance south of the main ridge, in Licking County. On the farm where I lived there had evidently been large numbers of arrow-heads manufactured, judging from the piles of fragments, broken arrows, and pieces of lances found on the surface. Many of these were composed of a bluish limestone, found in and north of the ridge, where numerous pits yet remain. When first quarried, the stone splits easily, and is soft, but, on exposure to the air and sun, changes color, and becomes extremely hard. There is also a flint, or hornstone, found on or near the surface in that locality, which is of a dark color, sometimes streaked or mottled with white, from which large numbers of arrows have been manufactured, and are found scattered all over Ohio.

These implements were probably made by the earlier Indians of Ohio. It is not unlikely that they were carried there for immediate use. Their form, sharpness of fracture, and shape are so symmetrical and complete, that we are led to conclude they are finished. If they had been intended for further manipulation, their finish would have been less perfect. When Smith was on this stream in 1755, bark canoes were exclusively used by the Wyandots and Delawares.

Some of the spear-heads are very rare. Five were picked up near Ashland. I call them spear-heads, though it is uncertain for what purpose they were used. They are generally well finished, and have been used. Some of them are of an unknown flint. I have never seen the blueish kind in the "Flint Ridge" material. The first is intensely black; the second, of a brownish black; the third, on being fractured, presents a blue color; the fourth is a drab, or sort of dirty white, and is very delicate in structure, and extremely sharp; the fifth, on being fractured, exhibits a blue color, and is peculiar in shape.

A singular instrument was picked up by Mr. Briggs in the neighborhood of the nest of flint-implements. It is made out of a sort of greenish-gray stone, variegated. It possesses a high polish, and the material is quite hard. A hole in the center is neatly drilled. It may have been suspended from the neck as an ornament.

THE AGE OF STONE, AND THE TROGLODYTES OF BRECKINRIDGE COUNTY, KENTUCKY.

BY R. S. ROBERTSON, OF FORT WAYNE, IND.

The remains of the stone-age are abundant on both sides of the Ohio River, proving that its shores were occupied by a very large population long anterior to the advent of the whites.

My attention having been attracted to reports of human remains found in a cavern or rock-shelter near Hardinsburgh, Ky., I visited the locality May 12, 1874, but was not early enough to forestall the vandalism nearly always displayed when such remains are discovered, and by which many valuable relics are destroyed, or scattered and lost. Nearly everything of value to the ethnologist had been dug out and carelessly destroyed, and out of thirty or more human skeletons of all sizes, from infants to adults, exhumed, I was informed that only one skull had been preserved, but as that is in the possession of Prof. N. S. Shaler, State geologist of Kentucky, we may expect to hear something of its characteristics.

Hardinsburgh, the county-seat of Breckinridge County, is eleven miles southeast of Cloverport, and in a hilly, broken country. About a mile and a half northeast of the town is a range of high hills, at the base of which runs Hardin's Creek, now nearly dry. These hills are capped by high limestone ledges, cut through in past ages by some powerful erosive agency, leaving the general course of the cliffs on an east and west line, but cut by lateral fissures and valleys. The rock has been so eroded as to leave overhanging shelters at several points, some of which are of considerable size. One, particularly, seems to have been occupied by man for a long period, and when it ceased to be used as a habitation, became the sepulchre of the remnant of its occupants, who were probably massacred and left in the ashes of their home, on the final extinction of their tribe. The cavern is open toward the south, the overhanging roof protecting the space below from any exposure to the elements from above, while immense masses of fallen rock make a wall from ten to twelve feet high, directly in front, between which and the rear wall of the cavern the deposit containing human remains was found. This deposit consists almost entirely of wood-ashes, so dry that clouds of dust arose while working in them, and we sank nearly to the knees at every step. The deposit is about eight by fifteen feet superficial measure, and was about seven feet in depth. In it, without order, were found thirty or more human skeletons, nearly all with a flat stone laid upon their heads. There were infants and adults promiscuously buried at various depths in the ashes, and at the bottom, on a layer of broken stones, some charred human remains were found. The bones had been thrown out and broken, so that none remained worthy of preservation; but from a description of the skulls found, I should think they were of a marked dolicho-cephalic type, with flat, receding foreheads.

Mingled with these remains many flint and other stone implements and weapons were found, with a few fragments of rude pottery, such as is commonly met with all over the country. I could learn of no ornaments, except some shells of the common muscle, perforated for suspension. Two perforated stones, of the kind supposed to be weaving-shuttles or thread-gauges, had been found, but carried away.

The polished and drilled ornamental stones found frequently in other localities seemed to be entirely absent here, indicating that these cave-dwellers had not advanced beyond the strictly useful arts. I found in the ashes a number of arrow-heads, scrapers, and knives of dark flint, a stone hatchet, and a buckhorn handle for a poinard or knife, similar to the handles of some modern hunting-knives. These were all found in the ashes which had not been disturbed. Quantities of flint-chippings lie around, and a stone, on the surface of which are fourteen small circular depressions, disposed in two nearly parallel rows.

To the left of this large shelter, and under the continuation of the same roof, is another on a high shelf of rock, reached by climbing on the fallen rocks which form the front wall. It is large, but does not afford standing-room in more than half its area, but has been used, perhaps, as a sleeping-apartment, as the rocks by which you reach it are worn smooth.

Immediately in front is a steep descent of about one hundred and fifty feet to a brook, now dry, and, at a corresponding elevation on the opposite side, is another high cliff, perpendicular on its northern and overhanging on its southern face. Here many chippings of flint, some arrow-heads, and a flint knife were found, as if it had been used, also, either as a dwelling or workshop. It is not so large or so well sheltered as the other. My guide informed me of several other rock-shelters and of some stone-walled graves in the vicinity, which I had not time to visit. Although the flint used is easily worked, the articles found were all of ruder workmanship than those found at many other places.

In the road just outside of the town of Hardinsburgh I noticed a number of characters and figures cut in the surface of the flat rocks here exposed; .some of them are partially obliterated by travel, but they still occupy a large space. As there are many smooth rock-surfaces exposed in the vicinity, and none other exhibited these marks, I had no hesitation in considering them to be the work of man, and afterward learned that it was called "Indian Rock." The tau, T, is frequently seen, while other marks are in the form of the Greek cross, with shorter arms above than below. Others, and these the most numerous, were a combination of the latter with other lines, Ӿ X̄, and some other characters I cannot now describe, having lost the drawing I made at the time.

At Cloverport I spent some time on the river-bank searching for remains, and was rewarded by finding a number of flint weapons with many chips or flakes, and, on the boys of the neighborhood becoming aware of the objects of search, they brought me large numbers, many of them of interesting shape and workmanship. The bank here is a long, gravelly slope up from the water, above which are successive steps or benches of clay, bounded by a perpendicular wall of clay. It is on the uppermost bench of clay that nearly all the specimens, finished and unfinished, and the chippings, are found. Those found below this point invariably appeared to have been washed down.

The boys assured me that they could take me to a point across on the Indiana shore where I could get a wheelbarrow-load, but as I had neither time nor wheelbarrow, I was forced to forego the proposed visit.

I have no doubt that thousands of specimens could be obtained by a visit to the landing-places on both sides of the river between Louisville and Evansville.

One specimen shown me, but which the owner refused to part with on account of some superstitious regard, considering it in the nature of a charm, was sixteen inches long and five broad, in shape nearly like a willow-leaf. It was a white, cherty limestone. I heard of a large stone pipe found two years ago, but after an active search where last seen no trace could be found of it. The children had been allowed to use it for a plaything, and it had thus been lost.

Returning to Louisville, during a stroll of perhaps a mile on the river-bank below the cement-works, and upon the same clay bench, I found several complete and many broken specimens of worked flints, and this where many people pass and repass every day.

On the whole, I conclude that the men of the stone-age who occupied the shores of the Ohio and dwelt in the caverns and rock-shelters of the interior, had not advanced to that stage of the arts which led men to give a beautiful finish to their weapons and to carve and perforate stones for ornament or for badges of authority, like the prehistoric men of many other localities, but contented themselves with such implements and weapons as the necessities of their wild life required, without spending much time in giving artistic touches to their manufactured articles.

ANTIQUITIES OF ISLE ROYALE, LAKE SUPERIOR.

By A. C. Davis, of Detroit, Mich.

I send you three photographic views of a mass of copper found in clearing some ancient mine-pits on Isle Royale, Lake Superior. The mass was found in the bottom of a pit sixteen and a half feet deep, and was completely detached from the surrounding rocks. All the wings have been beaten off by the ancient miner with his stone hammers—evidences of which can be seen all over its upper surface. The section it was taken from is 27, 66 north, range 35 west. The belt of rock in which it was found is of a sedimentary character, highly metamorphosed, from twenty to forty feet wide, and for a distance of two and a half miles has been completely worked over by the ancient miner. I have been mining for the last twenty-five years on Lake Superior, but I have never seen anything to compare with this locality for ancient work.

I am confident that, when this district is thoroughly mined, discoveries will be made throwing more light than we now have on the character of the people who did this work.

In the depression in the outlying trap was found clean lake sand, and the rock thrown out of the pit first was thrown on the sand. There was no sign of vegetable mold between the rock and sand, but over all there was three and a half feet of made soil or decomposed vegetable matter.

In the pit there are tons of stone and stone-hammers, and a large quantity of ashes and charcoal.

In one I opened on a transverse vein on the same property, I found the scales of white-fish. At this pit the ancient miner had used large granite bowlders to hold up the hanging ground. These bowlders would weigh from 300 to 400 pounds, and were put in where the modern miner would place timber, to secure the ground. Nearly all the brands and timber we found in the pits were roots and stumps. This, with the fact of their using these large stones for timber, leads me to think that the ancient miners had used up all the timber in their reach, and consequently could not prosecute mining further.

There is another peculiarity in the hammers found in these mines—I only found one that was grooved, while on the south shore of the lake I never saw a stone-hammer that was not grooved.

ANTIQUITIES OF YAZOO COUNTY, MISSISSIPPI.

By J. W. C. Smith, of Benton, Miss.

There is a mound on the Yazoo River, twenty miles below Satartia, worthy of note. It is situated at the foot of a tall bluff, and near the river. At the base it is, perhaps, one hundred and fifty or two hundred feet in diameter, fifty feet high, and flat on top; some fifty or sixty feet across. It evidently is the burial-place of some noted chief, and must have required months to build it, and the nearness to a high bluff precludes the idea of its having been built to escape from water. There are several smaller mounds in the neighborhood. Perhaps some scientist at Vicksburgh will explore it for you on application.

Near Carthage, in Leake County, Mississippi, there is a small branch in which are many articles resembling petrified terrapin or tortoise heads; and where at one time was found here the genital organs of a man, also in stone.

ANTIQUITIES OF TENNESSEE.

BY DR. DANIEL F. WRIGHT, OF CLARKSVILLE, TENN.

The locality in which the relics sent to the Smithsonian Institution have been collected, has been known as the "Indian grave-yard" as far back as any of the present inhabitants can remember, and has been more or less noticed according to the condition of the superincumbent soil as affected by successive inundations of the Cumberland. Thus, for many years prior to the present date, the graves from which these relics have been taken have been buried some eight or ten feet deep by the fluvial deposit, and have been forgotten by the present generation; but since the inundation of last spring, through some change in the current, the receding waters have produced a contrary effect, and washed the graves completely bare, leaving the skeletons only covered with the stone slabs placed over them at the time of burial. The location is about fifty yards from the left bank of the river, and about three miles above Clarksville.

The following considerations will, I think, be deemed conclusive as evidences of its having been a permanent and rather populous settlement of some tribe:

1st. *The nature of the graves.*—These are elaborately constructed. It is impossible to say how deep they were at the time of excavation, on account of the shifting character of the soil above described; but every grave has a slab of shale-stone at the bottom; upon this the body lies, and additional slabs are placed at the head and feet, and on each side, all rising to the same level, which is rather more than high enough to cover the body. Finally, on the top of the inclosure so formed a large horizontal slab is placed, completely covering the whole; the earth is then thrown in, and the body thus left inclosed not only in a well-protected grave, but in a complete stone coffin. In one place (and only one) a peculiar arrangement of the graves is noticed. Five or six graves are so placed together that all the heads are nearly in contact, while the feet radiate outward so as to mark out the circumference of a circle something over twelve feet in diameter. On the whole, I suppose that more than forty skeletons, each in its separate grave, have been taken up since the last overflow.

2d. *The evidences of manufactures habitually followed.*—These are flint weapons and implements and pottery. Where the greater part of the flint-implements were found innumerable chips and flakes of flint were also observed, such as are struck off in the manufacture of flint articles; these are found in great abundance. In reference to the pottery, still stronger evidence of its being manufactured on the spot was discovered. We found an excavation of a circular form about six or eight feet in diameter, and four or five feet deep, which had been loosely filled with sand that was easily removed; and in shoveling it out, there were found mixed with it in great abundance fragments of pottery, a quantity of charcoal, many charred and half-burned pieces of bark which had passed through several stages of combustion, some of them being in part entirely unaltered by the fire; and, above all, several large lumps of unworked clay, partially hardened by fire. The neighbors inform me that this clay must have been brought from a considerable distance, as none like it, and, indeed, no clay at all, is found within many miles of this place. In the specimens of pottery sent, I would call your attention to the peculiar markings on the concave surfaces of most of it. I at first supposed that these were made by some artificial process for decorative purposes, though it seemed strange to place decorations inside the objects; but a neighboring gentleman called my attention to the exact resemblance these markings bore to the corrugations on beech-bark, and I was led to the conclusion that the pottery had been molded around an interior core constructed of beech-bark. I think there is no doubt but that the excavation I have described was an oven or kiln for baking the pottery.

3d. The presence of infant skeletons in great number, buried with the same elaboration in all its details as above described in the case of the adult sepulchre. Some fragments of cranial bones from these are inclosed in package No. 7. The undeveloped and imperfectly ossified condition of the infant cranium renders it improbable that entire infant-crania will be discovered; which is the more to be regretted as it would be interesting to observe the bones in the early stage of the flattening process, which seems to have been customary in this tribe.

To sum up this part of my view, then: The elaborate and substantial character and large number of the graves, the evidences of arrangement for the manufacture of stone implements and pottery, and the presence of a considerable number of infant skeletons, all carefully buried, satisfy me that this burial-place was an appendage to some permanently-occupied Indian village.

But, when? There are some considerations which seem to throw us back upon prehistoric times for an answer—that is, what are to us Americans prehistoric times.

In Europe, these flint-weapons would carry us back to the mysterious nationalities which occupied the site of Troy before the Troy of Priam and Hector existed, or to those unknown tribes which lived in Hebron before the seed of Abraham had germinated in Palestine. With us, prehistoric times come down to a much more recent period. Anything previous to the permanent occupation of a region by the European races is with us prehistoric, and west of the Rocky Mountains there are tribes still in the *neo-lithic* stage of development, using just such flint arrow-heads and hatchets as I send you, to-day.

The evidences that, relatively to the Boones and Donelsons and Robertsons who first settled these regions, the remains now under discussion are prehistoric, are as follows:

First. I have had conversations with very old settlers—persons whose recollections extend back fifty and even sixty years, and they report that no Indian village existed in that locality or anywhere near Clarksville; and not only so, but they speak of conversations with the Indians, who, in their childhood, frequently came here on hunting-expeditions, and that none of them knew of any tribe or had any tradition of any who ever had any permanent residence either near this burial-place or in the region at all; it was never within their knowledge anything but a hunting-ground.

Secondly. In his first visit to Kentucky, Daniel Boone spent a whole winter encamped near the mouth of Red River, (a small affluent of the Cumberland;) in other words, on what is now the site of Clarksville; and that during that winter he did not see a single Indian, the country being only visited for hunting-purposes in summer-time.

This last statement I have on the authority of my friend, Professor Stewart, well known to your Institution. I have no means of verifying it by documents, though in Washington you have, I suppose, the means of doing so in the National Library.

Supposing, then, that I have rightly interpreted the facts so far before us, we are thrown back on all prehistoric times for the period of our village's existence, and have no means of determining whether it dates before or after the discovery of the American continents by the European races.

The small package, No. 8, contains an invaluable relic in reference to our chronological difficulty. On examination you will find it to be a leaden bullet, completely covered with a bony accretion. This was found in close contact with the scapula of one of the exhumed skeletons. The manner in which it is enveloped with bony matters convinces me that it was lodged in the shoulder long before the Indian's death, and carried there for years. This proves that the Indians in question had relations, hostile at least, if not more intimate, with persons possessing fire-arms, and so brings down the antiquity of our village to a date subsequent to the appearance of the European races in the valley of the Mississippi.

The closest estimate, then, we can make of the period when the village existed from which these relics are derived, is that it was prior to the permanent settlement of this portion of the basin of the Cumberland, and subsequent to the first visit of European races, which still leaves us a range open to conjecture extending from the middle of the seventeenth century to, say, the time of the revolutionary war—a range of from one hundred and twenty-five to one hundred and fifty years.

This much premised, I would call your attention to some matters of detail in the relics to which this paper refers.

Opening the packages Nos. 4 and 5, I think you will be struck by a great diversity in the workmanship of the different articles. Thus, most of them are as roughly chipped out of the original flint as anything we know of in the rudest paleolithic times, and others are shaped with some artistic skill to a predetermined form. Give your special attention to one article in package No. 5, wrapped in a separate piece of newspaper—probably the blade of a tomahawk. You will observe that it is ground down to a preconceived shape with a precision and finish which would do credit to a modern lapidary. I have also given a separate envelope to a curious implement made of a thin lamina of flint, in package No. 4. I am informed by persons acquainted with present Indian usages, that an exactly similar implement is now employed to scrape clean the inner surface of raw hides, prior to curing them for use.

Now, a few words about the three crania. Those in the packages 1 and 2 present the ordinary type of the Indian skull; narrow, with a low facial angle, and with the prognathous character very strongly marked in the facial bones—these characteristics being most pronounced in No. 2. But No. 3 rather puzzles me. The American Indian type is here much less pronounced, the facial angle higher, and the prognathous type scarcely marked at all. In all respects it seems to approximate the Caucasian type. You will also observe that the process of artificial flattening, so common among Indian tribes, has been applied to Nos. 1 and 2 with complete success, the flattening of the occiput being so great as to render the plane extending from the occipital condyles to the vertex absolutely vertical.

Now, on No. 3 this process has been very incompletely effected, having succeeded not at all on one side, and only imperfectly on the other.

If I knew more than I do of the tribe whose remains we are studying, I think I should venture upon the conjecture that No. 3 is the cranium of a half-breed, which would imply a still more intimate association with the white race than that short and sharp interview suggested by the impacted bullet.

Such as they are, however, the foregoing remarks are submitted to your riper judgment; they have been considerably longer than I anticipated when I commenced them, but I think that some interesting problems are suggested by the relics, and could not resist the temptation of attempting a solution.

I should remark that, although a large number of entire skeletons was exhumed, I did not see much to be gained by sending you anything beyond the crania. The only thing really noticeable about them was their great thickness, especially that of the maxillaries and the bones of the extremities; some of the femurs, though evidently not those of tall men, would, in bulk and weight, largely surpass those of any white man I have seen.

I forgot to state that the crania Nos. 1 and 2 are presented by Dr. W. T. McReynolds, of this place, who had obtained possession of them before my exploration.

ANTIQUITIES OF BLOUNT COUNTY, TENNESSEE.

BY MISS ANNIE E. LAW, OF HOLLISTER, CAL.

The relics sent were all found in the vicinity of a large mound in Chilhowee Valley, on the banks of the Little Tennessee River, Blount County, Tennessee, except the beads and axes, which were found on Tellico River, Monroe County, Tennessee. The mound in Chilhowee Valley was partially washed away during a high tide. It contained seventeen skeletons buried in a sitting posture, surrounded by stone slabs. The mound was some twenty-five feet in diameter, and the graves were in three tiers. With each had been buried water-jugs of crumbling pottery, beads, and stone implements. These had been carried off by relic-hunters before I was there. Those I got were plowed up afterward from sand-beds in the bottom-lands, where the strong current had carried them.

ANTIQUITIES OF ORLEANS COUNTY, NEWYORK.

BY FRANK H. CUSHING, OF MEDINA, N. Y.

In the town of Shelby, Orleans County, New York, about three miles southwest from the village of Medina, are the remains of one of the most interesting ancient earthworks in the State.* This work is situated at the summit of a slight and not abrupt elevation. It consists of two mural embankments, which are now about two feet in height parallel, and twelve feet distant from each other. They describe almost an exact circle, having a diameter of four hundred and thirty feet and an area of three and one-third acres. Two fences upon original "section-lines," running, one north and south, the other east and west, divide this inclosure into four nearly equal parts or quadrants. Those portions of the work included in the northeastern and southwestern quadrants have for many years been under cultivation, and the embankments are nearly obliterated. The northwestern and southeastern portions are still covered with forest-trees. In these portions the walls are interrupted only by two sally-ports or openings for passage. These openings occur at nearly opposite points in the circle. The passage through the outer wall is not in either exactly opposite to that through the inner. In one they are sixteen and in the other thirty feet apart. To avoid two large bowlders of Niagara limestone, the inner wall at one point makes a slight deflection from its regular circular course.

Upon these embankments are standing trees and the stumps of trees that had commenced their growth long before the Jesuit fathers had explored the region now comprising Western New York. Traces of a moat which once encircled this work are still discernible at intervals. This moat is broad in proportion to its present depth, and in this respect is not regular. It was probably made by the removal of earth for the construction of the walls, and perhaps it was not intended as an additional defense, though it must to some extent have served as such.

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* This work has previously been described in Squier's Aboriginal Monuments of New York, Smithsonian Contributions to Knowledge, vol. II, 1851.

Three features presented by this work add much to its interest: first, it is almost exactly circular in form; secondly, it consists of two parallel embankments; thirdly, the openings for passage are not opposite in the two walls. These three peculiarities distinguish this from all other earthworks known east of Ohio.

Ten rods south of this work lies a peat-swamp, two miles in length by one in breadth. This swamp is or has been covered by a heavy growth of black-ash timber. A vertical section of seven feet in this swamp shows first the remains of trees to the depth of two feet, next below the remains of marsh-plants, gradually becoming peat, which, as the depth increases, changes in character and color from dark brown to light blue. At all depths in this peat are to be seen the remains of leaves evidently brought by the winds from the forests of the surrounding higher land. Underlying this peat is a stratum from three to five inches in thickness, composed entirely of fresh-water shells, mostly univalves; some of which are apparently species of *Pauludina*. Beneath this stratum there occurs another, composed of blue clay, intermixed with sand, containing occasionally the remains of shells, among which have been found specimens of the fresh-water clam, (*Unio.*)

These facts lead to the conclusion that this peat-swamp was probably a shallow lake at the time when the works were constructed. This conclusion is also strengthened by the fact that there is no evidence of the existence of a permanent supply of water elsewhere within a mile of the work.

It is proper to state that the supply of fish in this ancient lake was abundant; replenished during the time of high water in the spring of each year from Lake Ontario, thirteen miles distant, through Oak Orchard Creek, into which its outlet flows.

West from the work, at a distance of half a mile on the eastern slope of a sand-hill, is a large "bone-pit," where the bones of many hundreds have been deposited. It is said by "old settlers" that those portions of the work now included in the cultivated fields spoken of, originally presented the same features now seen in those which the forest includes.

Of course exaggerated stories are told of the relics which have been plowed up in these fields. Without doubt many which would be of great interest to an ethnologist have been found, kept for a while, and then given to the children as playthings by those who knew nothing of their value as relics.

On making excavations in those portions still uncultivated, many specimens of great interest are found. They usually lie from six to eighteen inches beneath the surface, often imbedded in charcoal and ashes. They consist of hammers, sinkers, celts, stone ornaments, pipes, pottery; also implements and ornaments of bone, such as bone splinters, awls, and needles, daggers or dirks, cylindrical ear ornaments, implements for the ornamentation of pottery, perforated metatarsals, and perforated teeth. These bone implements are found in all stages of manufacture, from the rude splinter to the ground and polished implement or ornament.

What was the original height of these works can now only be a matter of conjecture. It is probable, however, that the embankments were from four to five feet in height and surmounted by palisades. Vegetable mold to the depth of six inches has accumulated upon those points most elevated and exposed to atmospheric action; beneath this stratum the relics occur to the depth of eighteen inches. The inference, therefore, is that since the work was abandoned time enough has elapsed for the accumulation of this six inches of vegetable matter by the slow process of growth and deposit on dry land. It was inhabited or used long enough for twelve inches to accumulate. It was probably abandoned when the lake was so nearly filled that it ceased to afford either fish or a permanent supply of water. Since the time when timber commenced to grow at the surface of the lake, two feet of vegetable matter have accumulated.

ANTIQUITIES OF LA PORTE COUNTY, INDIANA.

By R. S. Robertson, of Fort Wayne, Indiana.

At Union Mills, La Porte County, is located one of the most remarkable groups of mounds to be found in Northern Indiana.

Union Mills is a small village, with a beautiful location on the high table-lands between the great Kankakee Marsh and Lake Michigan, most of the village being on the east side of Mill Creek, which furnishes a fine water-power for the mill from which its name is derived, and which flows southwardly through a ravine some 40 or 50 feet below the nearly level plain on which most of the mounds are situated. To the southwest another ravine terminates this table-land, beyond which are a series of ridges and levels gradually merging into the Kankakee Marsh, which is here, however, generally drained and cultivated. Along the brink of this ravine, ten (or rather five double) mounds have been raised, of nearly uniform construction, and all evidently for places of sepulture.

Where the mounds are double, as all of this series are, the larger one is now about 10 feet in height, and its companion about one-third lower. The longitudinal diameter of the two is about 150 feet by from 60 to 70 feet across, and they are from 50 to 100 feet apart. The small mound at each end of this series is thrown back nearly at right angles with the general line, as if there were an intention on the part of the builders to make these terminal points for the group.

The first or northernmost large mound was almost entirely cut away some time ago in constructing the Peninsular Railway, which runs directly through it; and the third large one was nearly half cut away by the wagon-road, whose track here runs below the base of the mound. The next has been partially leveled and a farm-house built on its truncated base. There are no depressions in the surrounding surface, showing that the materials, which in some are sand and others surface-loam, have been brought to the place from some other point.

Proceeding eastward to the bank of the creek, we find another mound, (No. 6,) which has been leveled to a terrace-form about 4 feet high, on which Mr. Flanigan's house stands; and directly north, across an arm of the ravine, was another, (No. 7,) whose site is occupied by the house of Allen Cummings. Across the creek, nearly east of this, is a very large round tumulus, (No. 8,) which is about 15 feet high, with a base of about 100 feet. One hundred feet north of this is another double mound, (No. 9;) the smaller one of the group is in the yard of a church, and the larger one just in rear of it.

I could find no traces of fortifications, and there are no other mounds in the immediate vicinity, but I was informed that a large group exists on a rolling prairie about two miles east, of which a very large one was leveled several years ago. This is, perhaps, the same group examined by Dr. Higday, of La Porte, some years since.

My informant also states that about a mile south of Union Mills is a burial-place of the modern Indians, still known as "Indian Fields," from which bones, medals, kettles, guns, &c., have been obtained, while a half mile farther south, on a prairie overlooking the Kankakee, is another group of seven or eight mounds. These different burial-places would, undoubtedly, prove of interest to the ethnologist, for a comparison of the remains of the two races who practiced such different modes of burial.

The greatest interest in these prehistoric remains centers in the fact that the crania of the mound-builder, as found in these tumuli, differ widely from those of any known race, approaching the Neanderthal skull in type, and being, perhaps, lower in development. The frontal bone recedes backward from a prominent superciliary ridge, leaving no forehead, or rather the eye looks out from under the edge of a frontal plate, which reminds me of a turtle-shell and is scarcely more elevated. My specimen is lower than the Stimpson-mound skull, and even than the Neanderthal, if we can judge correctly between the actual and the pictured skull. None have yet been found here with the skull or bones entire.

In my examination of the group I concluded that the road cut through No. 3 had passed a little south of the center of the mound, and selecting the sloping bank of the roadway as the easiest point to excavate with favorable results, I was rewarded, after a few minutes' work with pick and shovel, by finding several flakes of a white flinty stone, and then some fragments of bone, after which the hands were the principal tools used to complete the work, lest I might injure the decomposing remains.

The skeletons of two individuals were found, all in a confused heap, occupying a space less than two feet square, except that the leg-bones were extended in different directions, perhaps a foot farther, each way. The skulls had evidently fallen down upon the other bones of the skeleton, and all had been crushed together by the falling earth. They had evidently been buried in a sitting posture, back to back. While exhuming them I concluded there were but two persons, but on a more critical examination I find some fragments of a lower jaw, which lead me to think there may have been three.

Most of the bones had become as soft as the surrounding earth, and while I could see and follow their outlines it was impossible to remove them, except in fragments. One upper jaw was perfectly outlined in the earth, with the full row of teeth upward, but it crumbled to powder on attempting to remove it. The skulls were crushed and the lower fragments were in the same state of comparative decomposition. I secured the right half of the frontal plate of one and the lower jaw nearly entire. The teeth were worn flat, indicating great age and hard food. The molars and five incisors were perfect, but both canines and one incisor had been lost and the bone had grown over and closed the cavities. I regret that these teeth have nearly disappeared in drying, falling to pieces like slaked lime.

I also secured a fragment of the right frontal bone of another individual, which I conclude to be that of a female, from its difference in form, and from the fact that the teeth in the fragments of the jaw found with it indicate mature age. The teeth are perfect and beautifully white when washed.

Neither pottery nor weapons were found in this mound, but in the one through which the railroad was cut were found a stone pipe of beautiful workmanship, two awls of native copper, a large earthen jar containing a black substance, and an earthen bowl, which are described as having handsome designs on the surface, but which were broken and lost, and ten spear and arrow heads, five of which I secured and have represented. They are of a white flinty stone, with a delicate chipping, and are quite thin. The form is different from any of the hundred or more specimens in my cabinet, which are mostly "surface-flints."

Since I was there I learn that there have been exhumed from the small mound on the railroad bank, (No. 1,) a copper hatchet, which, from the description, I conclude to be similar in form to the European bronze "celt," two more copper awls, or needles, and two jars of pottery, both broken. I have made arrangements to secure them. These remains, as near as I could determine, are found on or immediately below the original surface. The earth in the mounds is as hard and compact as the surrounding strata, and immediately around the skeletons is discolored. I dug through about six inches of black loamy earth before coming to the bones. They were found in what was nearly the exact center of the mound.

At Hascall, a few miles west, I found a small ball of baked potter's clay in which pounded shells had been mixed. It had been squeezed up by the hand just as we see children form balls of dough or putty. It is of the color of Philadelphia brick. What is remarkable about it is, that notwithstanding the lapse of time since it was baked it not only shows the marks of the fingers, but even the lines of the skin are clearly impressed on its surface.

Some phrenologists would say that a race with foreheads like those of this race had no brain capacity, and could have no intelligence. Yet they fabricated and used tools and weapons, some of which are of fine workmanship. They understood the ceramic art, and that they had a religion no one can doubt who reflects that they erected such monuments to the memory of their dead chiefs, or showed such care for the safety and comfort of their passage to the spirit-world as exhibited in placing beside them jars of food and water, their pipes and weapons, and perhaps by their sacrificing and burying with them their favorite wives. It is difficult on any other hypothesis to account for these facts.

ANTIQUITIES OF ALLEN AND DE KALB COUNTIES, INDIANA.

By R. S. Robertson, Fort Wayne, Ind.

I inclose by to-day's mail manuscript description of mound-remains in Allen and De Kalb Counties, which I hope may be considered worthy of a place in your report. I think it important to describe locations of mounds as far as discovered, and when Northern Indiana is fully explored, it will prove rich in prehistoric remains.

I have been careful to defer noting anything from reports, which are almost always much exaggerated, until I can verify them by personal examination. For instance, some ten days since I rode twelve miles in carriage and ten on horseback and return, to visit a fortification and mounds in the north part of Huntington County, only to find a very large beaver-dam. As reported to me, it was said to inclose from 150 to 200 acres. I found a beaver-dam, in zigzag lines, nearly 1,000 feet in length, and half a mile farther on two more, one about 300 and the other 600 feet long.

Since my paper containing a description of the location and contents of the mounds at Union Mills, I have received from there a copper implement 4¾ inches long, 2¼ inches broad at the cutting-end, and 1 inch at the other, and ⅜ of an inch in thickness. It is slightly convex on one side, and has apparently been flattened by hammering. I class it among the hatchets of the "Age of Copper," although it has no groove for the handle. It was exhumed from one of the small mounds of the group described by me, and with it was a copper awl or needle 3 inches long, pointed only at one end. The same mound furnished fragments of two different vessels of pottery, one deep and narrow, with bands cut in chevron patterns upon the outside. The other was apparently about the shape of the glazed earthen vessels used by our farmers for milk-pans. The outside of this has been highly ornamented with cut and indented patterns, but the device cannot be made out from the fragment in my possession. Its inner surface has been smoothed by pressure, I think, upon a potter's wheel. Bones of a single skeleton were found in this mound, but unfortunately no record was taken of any peculiarities.

During the summer I have investigated the prehistoric remains of Allen and De Kalb Counties as far as my opportunities would allow. All that I have discovered thus far have been in the vicinity of the Saint Joseph River, which flows from the northeast to the head of the Maumee and of one of its tributaries, Cedar Creek, which flows from the northwest into the Saint Joseph. I know of no mounds on the Saint Joseph much above the mouth of Cedar Creek; and the greatest number are on the creek in De Kalb County and the northern part of Allen.

Near Waterloo, in De Kalb County, R. W. McBride, esq., an enthusiastic archæologist and collector, had excavated two mounds, finding in one the remains of a great number of human skeletons, apparently buried in a promiscuous heap, and in the other, not far distant, a single skeleton. The bones were too much decayed for preservation. One of the skulls, he says, appeared to have been crushed by a blow from a blunt instrument. He found no works of art, but in examining the rubbish afterward with him I found the butt-end of an arrow-head of flint and a small fragment of pottery. These two mounds are about 50 feet apart, are about 30 feet in diameter, and about 4 feet in height, and are situated on the high ground bordering a marsh, which has once been a small lake. The remains were laid on the surface of the ground, covered with earth, and fires built, which baked the earth and calcined some of the bones. Quite a layer of charcoal and ashes was passed through in digging, and above this layer earth had again been heaped.

From there we went to Smithfield Township, six miles northwest of Waterloo, where, on the farm of Mr. Ruffner, is a circular earth-work about 600 feet in circumference, with two entrances opposite each other. The earth-work is from 2 to 2½ feet high, with a ditch outside. Very large trees, which grew on the embankment, have fallen and gone to decay, and a black oak standing just inside the wall measured 12½ feet in circumference at a height of 6 feet from the ground. The "fort" is situated in the woods, on a high piece of ground, which is nearly surrounded by ravines cut by the action of two streams now nearly dry.

We next went to the farm of Henry Gonzer, in Fairfield Township, where a mound once overlooked a small lake, which is gradually filling from the wash of the surrounding hills. The mound is now nearly obliterated by cultivation. We were informed by Mr. Gouzer that it was opened about twenty years ago, when a skeleton was found the thigh-bone of which was as long as his leg, and the skull as large as a half-bushel measure. We dug a little below the surface, and found a few bones, among which was a broken thigh-bone of the ordinary size, thus destroying a myth which has been a belief of the credulous of the neighborhood for twenty years, that "there were giants in those days," and that one was buried here.

The next day we visited a point five miles northeast of Waterloo, where there are several groups of mounds. In the woods on Mr. Boyer's farm we found a mound about 12 feet in diameter and 3 feet high, composed entirely of large bowlders. It has been there ever since the settlement of the country. On removing the stones and digging beneath, we found that the original soil had never been disturbed, and no remains were found. Near by in a cultivated field was another mound of earth nearly obliterated by cultivation. Excavating it, we found numerous bits of charcoal, and several fragments of pottery, but no human remains. A sort of trench from side to side had been filled with what appeared to be dried swamp muck. Its outlines were quite well defined in the sandy loam of the rest of the mound.

On the adjoining farm of Mr. Taylor, about half a mile distant, were two more mounds. We dug into one of them, finding again charcoal and fragments of pottery, but no human remains. None of these mounds are more than 3 feet high, and generally have a base of from 20 to 30 feet. All through this section many flints and carved implements and ornaments of stone are found by the farmers. Some of them are perforated, and nearly all are of the banded siliceous slate, which seems to have been so highly prized by the mound-builder. One found in this vicinity and now in my collection is represented in Fig. 2. The boy who found it described it as a "stone bayonet," and his mistake seems quite natural when we look only to the shape of the ornament. It is intended to represent a long-billed aquatic fowl, and was probably worn as a totemic emblem on the head-dress of a prominent chief, to which it was attached by thongs passing through the holes drilled in the ends. The tail is unfortunately broken off. Mr. McBride has several in his collection, some of which are fair representations of birds. He has one almost precisely like Fig. 27 in Foster's Prehistoric Races, and has also a *fac simile* of the implement found at Danville, Ill., represented in Fig. 28 of the same work. I have seen a number of articles carved from this ribboned slate, some of which are shaped like a double-edged battle-ax, but too slight for use. They all have a smooth, regular hole drilled through the center about ⅜ of an inch in diameter. I conclude they were carried as emblems of authority in processions on state occasions.

We heard of other mounds in De Kalb County, but had no time to visit them.

In Allen County these remains are not so numerous, and there are none at all in the southern part of the county.

On Cedar Creek, about ten miles north of Fort Wayne, is a group of four mounds, near Stoner's Station, on the Fort Wayne, Jackson and Saginaw Railroad. Two of them are in a line north and south, about 40 feet apart. About fifteen rods east of these are two more, about the same distance apart, on a line nearly east and west. Three of them had been opened years ago, and bones of a number of skeletons found in all. The fourth had never been disturbed, but an excavation disclosed no remains, out many fragments of charcoal and hard-baked earth. I procured in the vicinity a large stone ax and a spear-head of large white flint, leaf-shaped, and about 5 inches in length, (Fig. 7,) besides a number of smaller flints. These mounds are on the high ground at the junction of Cedar and Willow Creeks. About four miles south of these is a large, irregular-shaped mound, about 50 feet long by 20 in width. It is situated on the farm of Henry Wolford, whose family, being somewhat superstitious, would only permit me to dig a small hole near the center of the mound. About 2 feet from the surface I found an implement (Fig. 31) of ribboned slate, with a perforation near one end, of the class supposed by some to be a weaving shuttle, and by others an implement for gauging cords. Plenty of charcoal was found to a depth of about 4 feet. Below that for a foot the earth was very hard, as if baked, until the original soil was reached. I found no bones in this mound. There is no stream in the immediate vicinity, but a large marsh lies directly east of it.

At Cedarville, on the Saint Joseph, near the mouth of Cedar Creek, are three mounds about 100 feet apart, situated in a line running northwest, parallel with the general direction of the river at this point. None of them have been opened, but one has been partially removed to mend the road, and charcoal was found mingled with the earth.

Descending the Saint Joseph on the east side, to the farm of Peter Notestine, one of the oldest settlers, we find a circular "fort" in a bend of the river similar to the one in De Kalb County. It has been plowed over for nearly thirty years, but numerous fragments of pottery, flints, and stone implements are yet found in and about its site when newly plowed. Mr. H. J. Rudisill, county auditor, has a large rude pipe of pottery from this place. The bowl and stem are in one piece, and the end of the stem, which is nearly an inch in diameter, has been flattened by the fingers while plastic for a mouthpiece.

Still farther down the river, on the west side, opposite Antrup's Mill, is a semicircular "fort" with its ends on the river-bank. It is about 600 feet in arc. The earth-work is yet about 2 feet in height, with a well-defined ditch on the outside. Very large trees which stood on the embankment have fallen and gone to decay. We found in the earth which had been upturned by a fallen tree a fragment from the neck of a vessel, with square indentations on the surface, and a flint, flat on one side and regularly chipped to a concave surface on the other. Still farther down the river, at the mouth of Breckinridge Creek, is a single mound, which has not been opened, except a slight excavation, which developed the customary lumps of charcoal. This point is about four miles north of Fort Wayne, and is the most southerly point in the county at which mounds or earth-works are known to exist.

Still, on the ridges, implements and ornaments of the "stone age" and fragments of pottery are often found in many parts of the county, and many of these articles have a beauty of design and a polish unknown to the Indians who were found here on the advent of the whites. Some of the flints are beveled, and others seem to have been cut in a winding form, probably for the same purpose as the beveled ones—to give a rotary movement to the weapon. They are of every variety of flints or cherts, and one I possess is a beautifully veined agate. Professor Foster criticises Longfellow's lines—

> There the ancient arrow-maker
> Made his arrow-heads of sandstone—

and says, "Sandstone was never used by the mound-builders as a material for arrow-heads." I have in my collection a broken arrow-head chipped from sandstone, which proves that Longfellow was right and his critic wrong.

Some of the stone ornaments are of a material not found in this locality, except in a worked form. The ribboned siliceous slate seemed to have been held in special estimation, and I have part of one which I presume to have been an emblem of authority. It differs from any I have seen figured. It is of a reddish-veined slate, and had two perforations for the handle, but is broken through both holes, the intermediate piece being lost. The holes are about ⅜ of an inch in diameter, regularly drilled.

I send you with this rude drawings of other implements and weapons in my collection, which I have selected as types of the relics of the stone age found in this vicinity, and which I hope may prove of interest. They are all from this county, except those noted as from De Kalb. They are drawn the exact size of the originals, and the flaking and chipping represented as exactly as my artistic skill, or rather want of it, will permit.

ANTIQUITIES OF JACKSON COUNTY, TENNESSEE.

By Rev. Joshua Haile, of Gainesborough, Tenn.

[Communicated by James W. McHenry, of Nashville.]

There is a mound in this county, on the field of Mr. Philip M. Ray, about forty yards in diameter and [illegible]t high, though lower at present by several feet than it was forty years ago. This mound has been only imperfectly examined, and nothing found beyond a vessel or two made of clay and slightly burned. No bodies have yet been found in the mound or around it.

There are graves and a mound on my place, which have been carefully examined. The mound is near the middle of a valley, on the east side of Flynn's Creek, about one hundred and twenty yards from the stream. It is about forty yards in diameter and at the present time over 6 feet above the general surface of the land. Surrounding the base of this mound were placed loose, rough stones, forming a wall of 4 or 5 feet high. I have made excavations into this mound, and in different parts of it found that it is entirely filled in every part with graves just as close to one another as they could be placed. They are found at the present time from 18 inches to 2 feet below the surface, where there are no washings; this seems to be their usual depth. The graves are not confined to the mound, for the surrounding valley, containing fifty acres or more, is filled with them as close as they can be placed. These graves are generally in an east-and-west direction, and sometimes facing the southeast, and occasionally, where the rock interfered with the position, they are found without regard to direction, compactness seeming to have been the leading idea. A great many of these graves have been opened. They vary from 18 inches to 5½ feet in length, and skulls, with the jaw-bones still fastened to them, have been found; also ribs and leg-bones; in short, all the solid bones of the human body, with little sign of decay.

The manner of burying seemed to be as follows: The graves vary in width from 10 to 18 inches; the coffins consist of slates, at the bottom of the grave, closely fitted together; then slate set upon the sides and at the ends, all of the same height, of about 15 or 18 inches. These slates are generally in their rough condition, and the bodies seem to have been deposited, and then one or two slates or other stones, smoothly dressed or polished, laid over them. The stones are closely fitted together where two are used, and, from the compactness, seem to have been united with cement. The lid rests on the upright stones, and generally projects over the sides 3 or 4 inches. When these graves are opened, they are found dry within, and generally contain some toys, consisting of small jugs, crocks, skillets, or other small vessels, made of clay, with the image of a man, eagle, or some other bird, evidently stamped on them while in a soft state. The vessels vary in size from the capacity of a pint to that of a gallon. They have been burned slightly, but in no case have any been found glazed. There is at this time one of these vessels or jugs, at T. L. Settle's, in Gainesborough. Some of them have legs and handles.

These graves were first discovered about fifty years ago, when the valley as well as the mound were covered with a dense forest, composed of trees of a large size. A violent storm blew over some of the large trees, upturning the roots, and thus uncovered the graves

Contiguous to what may be called the valley of graves, on the west side of Flynn's Creek, is a low bluff, in which is a hole large enough to take in at its mouth an ordinary-sized barrel. This hole is the entrance to a cave under the hill, which has been explored to the distance of about 300 feet. This cave is high enough to allow walking in it erect, is quite roomy, and perfectly dry. In it was found, in 1863, a chest or box, made of black-walnut plank 1½ inches thick. It was about 2 feet long, 12 inches wide, and 16 inches deep, with a well-formed lid of the same wood. It was decayed on the outside with dry-rot to the depth of about 1 inch, and in some places the finger could be pushed through the wood; in other places the material was sound inside, and showed that the chest had been neatly dressed with a plane or some other tool, and lined with cloth or some fine, soft substance. In it were found wrapped up, in about three yards of large-checked gingham, a part of which was still sound, about twenty surgical instruments, consisting of a crooked knife, a crooked scissors, a lancet, and other articles of which I did not know the name. These instruments were not badly rusted, and in some places still quite bright; they were made of fine steel, finely polished, with handles of tortoise-shell. Dr. U. T. Brown, who has since died, took charge of them, and perhaps his family has some of them still.

On the hill, some 200 yards high, which joins this valley, is found a pile of loose, rough stones, 5 or 6 feet high. It has not been opened, and therefore no information is to be given as to its contents.

On the top of another hill, which joins the mound in P. M. Ray's field, about the same distance and height from the mound, is a similar pile of loose stones, which has not been examined.

ANTIQUITIES OF PERRY COUNTY, OHIO.

BY W. ANDERSON, OF BROWNSVILLE, OHIO.

I send to the Institution some specimens of antiquities from Perry County, Ohio. The mound from which they were obtained is 6 feet high, with a diameter of 25 feet. I found nothing until I reached the original surface of the ground, where there were ashes and charcoal. Two feet beneath these was the skeleton. The relics were deposited near its head. Around the neck was a string of beads of sea-shells. Near its right hand was found a plano-convex stone with holes in it. There were also a large number of arrow-heads and stone axes with and without grooves.

The skeleton was in a poor state of preservation. I saved a few bones. Around the skeleton was a quantity of ash-colored soil like that of decomposed bark. I send a specimen of each.

ANTIQUITIES OF CHARLES COUNTY, MARYLAND.

By Oliver N. Bryan, *of Marshall Hall, Maryland.*

The following paper does not propose to be an entire summary of all the Indian relics in this county, but only to present a list in part of such as have been found upon my farm on the Potomac, opposite Mount Vernon, and of a few found upon the adjoining estates. What I propose is simply to give a glance at my own cabinet, which I have been accumulating for the last ten or twelve years, and at a few specimens I, from time to time, have sent to the Smithsonian Institution.

Some ten or twelve years ago I became interested in gathering up, as opportunity offered, the stone arrow-heads, axes, &c., that happened to lie in my path, scarcely without knowing why I did so. At that time an interest in archæology had not developed itself in my mind, but now, with a taste somewhat cultivated in that direction, and more sharply eyed by practice, I take great pleasure in gathering up everything of the kind that falls under my observation bearing evidence that it can be referred to human ingenuity. I have become deeply interested in the subject, and earnestly desire to add my mite toward developing the history of the ancient people who lived upon the ground which I now call my own.

Among the articles I have gathered in my walks are axes, hoes, arrow and spear points, scrapers, and lances of stone and bone, wampum and pottery, pipes, needles with two holes, mortars, sinkers, hammers, chisels, paint-material, bones (human and brute) from Indian graves, and specimens from muscle-shell heaps. I have also found axes of greenish jasper, of various shapes and sizes, one of which I sent to the Smithsonian Institution; found about three miles from my house. It was double grooved and very long, and in respect to the extra groove was unlike any other that I ever saw. The arrow-points show a greater diversity of form and mineral than the axes or any other implement. I have them of quartz, jasper, agate, chalcedony, hornstone, flint, lydian-stone, and a very rough one of a granitic character. They vary in length from ½ inch to 4 inches.

It is evident that the makers of arrows could not work the stone, by chipping, to any desired form, as is proved by the fact that no two points can be found exactly of the same shape and size *in all respects.* Compare two of the same length and material and you will find one more umbilicated than the other, *bases* differently notched, points not true with the base, and many other different phases, which plainly show that the character of the mineral controlled the makers at least in part. This is not, however, the case with axes, pestles, or other implements submitted to a rubbing or grinding process. The makers of these had evidently a mechanical eye as good, as far as their range extended, as that of the mechanic of the present day. Nearly all the rubbed implements have their proportions wrought out, on both sides, as true to the design of the artist as could be done in our day upon such work.

Some of my arrow-heads have their points so crooked that one might fancy that they were intended to shoot around a corner. Besides arrow-points with bases to fit to the shaft, I have many without the projecting base, from one to three inches long; others with flat and thin bases, said to be war-implements, and to be left in the wound; and some few almost triangular. These last are generally more perfect than the *regular-pointed.*

The hatchets, so called, did not apparently answer the purpose of the modern instrument of the same name, and, so far as I can see, were never used by the Indian in that way. I have never seen one rubbed or worn, and this is true also of the axes. The latter were, in my opinion, used exclusively in war and in the chase.

Pottery seems to have been very extensively used among the ancient inhabitants of this region; some of very good quality, others very imperfect; some baked doubtless in nets, other as certainly without nets. I have one piece which, from its curvature, indicates a diameter of 17 inches, others from that down to 4 inches; none with ears or handles, but some with deflected rims. Some of the pottery has pounded chalcedony mixed with the clay of which it is composed; more, however, without it; another variety is worked out of soapstone or steatite. I have a number of pipes, one of clay, one of limestone, representing the human face and head in good style, and another of steatite showing a fox's head, a most capital representation. There are hammers in the collection, large and small, one weighing 8 pounds, 8 inches long, 6½ inches broad, 2½ inches thick.

Mortars are found on my farm. A broken corn-mill was sent from it a year or so ago; a medicine-mortar was also presented to the Institution. I have another, a paint-mortar, very unique, 4 inches long, and 2 broad, with a cavity on both sides (top and bottom) for the thumb and fingers to hold the article while the party is painting himself. The corn-mill was found three miles from my house. I think it singular that among the articles I have found on my farm there has not been a single corn-mill, although I have found a piece of a very large pestle. I have, however, two other very small mortars, which I suppose must have been for medicine or paint.

I have gathered since I commenced my collection, as stated above, everything that showed any trace of human art, consequently have quite a variety of unfinished pieces, some just begun, others more perfect, showing at once the implement to be formed. One piece, for instance, of yellow quartz, 10 inches long, 5 broad, 27½ thick, weighs 6 pounds, intended to be a spear; another quartz piece, cimeter shape, 15 inches long, 3½ inches broad, 2½ inches thick, weighs 6½ pounds, seems to be for a war-club, having a handle sufficiently developed for that purpose. There are also a variety of net-sinkers, very rough, of cobble-stones; needles, one of stone, 1½ inches long, ½ inch wide, $\frac{1}{16}$ inch thick, with hole and notch in one end; another, of horn, 7 inches long, ½ inch wide, very thin; a third, of bone, an inch long, of cylindrical form, constructed from the rib of some very small animal.

Wampum.—There are in my collection ten pieces of a bead, nine of shells, one of stone; another of shell, 4 inches long, ¼ inch thick. This last shows that the Indians must have had some communication with the ocean, as no shell now found in the river or bay would make such a bead. These wampum were taken from an Indian grave upon Piscataway Creek. There are doubtless graves in this neighborhood, but as yet I have not been able to find them. I heard, a few days ago, of some graves washed out, about fifteen miles below me, which I shall visit.

We have near my place several small "shell-heaps" of muscle-shells, *Complinatus*, nearly all weathered out, from which I have obtained specimens of pottery and bones of such animals as the ancient people ate. One remarkable bone was submitted to Professor Cope, which was pronounced by him to be the tarsus metatarsus of some large water-fowl, but I have examined all the skeletons of that class in the Smithsonian museum without finding anything like it. It might seem at first that the Indians here were driven from necessity to eat muscles, but from experiment I think otherwise. I have tried this mollusk, and find it, when well cooked, quite a savory dish, as good, to my taste, as common oysters.

We have also in this region and also in Saint Mary's the true oyster-shell heaps; one at Pope's Creek, covering thirty acres from one to six feet deep. Oyster-shell heaps abound upon the Wycomico River, and there are several in Saint Mary's County, upon the Potomac, the Wycomico, and Patuxent Rivers, and upon the bay. No ethnologist, so far as I know, has ever visited these localities. Although, near as they are to me, I have not yet visited them, intending to do so, I have been prevented by the constant recurring duties of the farm.

ANTIQUITIES OF STANLY AND MONTGOMERY COUNTIES, NORTH CAROLINA.

By F. J. Kron, *of Albemarle, N. C.*

I forward to the Institution, from Salisbury, N. C., by express, a small box containing some antiquities collected in this part of North Carolina, (the counties of Stanly and Montgomery,) on both sides of the river called Yadkin above and Pedee below the mouth of the Uharree River, on an area which may be embraced at a glance from the accompanying sketch, rough to be sure, but the bearings and distances of which are very nearly true.

From the vestiges left here by the Indians it must have been a place much frequented by them. They have now all disappeared from about here. Some fifty years ago, however, bands of ten or more were frequently met with on their way to Fayetteville, armed with bows and arrows, and ready for a reward to display their dexterity in hitting, before it came down, a piece of coin tossed up in the air.

Implements of war or the chase, broken pots, burned stones, where fires had been made, and arrow-heads chipped from minerals, are met with in all directions, in the bottoms along the river, and on the hills within a mile or so of the numerous fishing-stands along the banks of the stream. Between the mouth of Uharree and Island Creek, on the river-bottom, large spaces are covered with chips and blocks of chert from which pieces had been taken. The lands being all made by successive deposits from the stream, the remains are found from the surface down to the old bed of the river, to the depth of about four feet. Broken pots, of various material and ornamentation, can be picked up. Among those sent to the Institution will be found one heavy specimen of soapstone, a mineral not found in this neighborhood. Some years ago, a whole pot was washed up during a freshet, but the vessel, which was of about two gallons' capacity, and gourd-shaped, unfortunately fell into the hands of children, was broken, and only a few fragments saved.

Immediately below the mouth of Uharree River, across the Pedee, when the waters are low, there can yet be seen the greater part of a stone ford, in the form of a zigzag rail-fence. In 1829 it was still entire, and could be used for passing over the stream; but the stones have since been removed from both extremities for the building of fish-dams. What remains, however, indicates the sound engineering notions of the builders when they traced their path along a course the angles of which would divide the force of the stream.

No mounds nor vestiges of other permanent works are to be found. What remains seems to have been left on a vast camping-ground during the shad-fishing season, which in those days must have yielded a prodigious number of fish; for, not fifty years back, more shad could yet be caught than could be cured by the fishermen. Not so, however, now. Game must also have been an attraction, for the wild approaches of the river are, even now, much visited by hunting-parties of the white race.

ANTIQUITIES OF FLORIDA.

BY AUGUSTUS MITCHELL, M. D., *of Saint Mary's, Georgia.*

While in the South during the winter of 1848, pursuing the study and collecting specimens of ornithology, I was impelled by curiosity to examine a mound of a moderate size situated on the southern portion of Amelia Island, Florida, being kindly furnished with colored laborers, and aided by Dr. R. Harrison.

This mound was about 15 feet in height, and 30 feet in diameter at the base, flattened and worn by attrition for ages; there having been two growths of live-oak upon it, as stated by an old Spanish inhabitant of the place. The soil composing the mound was of a light sandy, yellowish loam.

We commenced the examination by cutting a trench 4 feet wide directly through the center, from the apex to the base, and then another trench at right angles to the former. The excavation revealed a number of relics, and the mode of burial of the mound-builders. They must have commenced by digging into the surface of the ground about 2 feet; then, partially filling the excavation with oyster-shells, they placed their dead on these in a sitting posture, their legs bent under them, with their faces to the east, and their arms crossed upon the breast, and next spread over them a stratum of earth. It is evident that in the successive burials the earth was reopened, and the additional bodies were placed close either to the back or side of those which had been previously interred, until the whole of the first layer was complete; then the circumference of the mound was walled in by a compost of marsh-mud; and then another layer of oyster-shells was placed over the heads of the first layer of bodies, and a continuation of the mud wall, until the superincumbent layer completed the mound to its apex.

Full three centuries must have rolled their tempests over this aboriginal repository of the dead. I quite expected to find everything like mortal remains returned to dust. But in this I was in error, as throughout the mound parts or complete portions of the bony structure still remained; those on the southern or sunny side being in a more perfect state of preservation. Counting the remains existing in the different layers of this ancient tumulus, it must have contained about four hundred individuals.

As we proceeded with our work, the interior of the mound presented many objects of interest to the ethnologist. We could not, however, secure many of these, since they crumbled, except the teeth, to dust as soon as exposed to the air. I had therefore to study them mostly in the earth, carefully scraping it away with a knife.

The conformation of the crania found in this mound appears to differ somewhat from that of the present Indians; the facial angle less, with superior depth of the frontal region, and greater capacity for the anterior lobes of the brain; the outer surface of the skull somewhat oval, smooth, and regular; frontal sinuses large; high cheek-bones; cavity of the antrum large; orbital cavity of the eye deep and large; occipital protuberance very large, with a great development of the organs of philoprogenitiveness; superior depth of the base of the inferior maxillary bone; rough serratures and deep depressions for the attachments of powerful muscles of that bone.

The teeth of many of the crania of this mound were, without exceptions, in a perfect state of preservation, the vitrified enamel of these organs being capable of resisting exposure for centuries. These teeth presented distinctive appearances throughout, in the absence of the pointed canines; the incisors, canine, cuspides, and bicuspides all presented flat crowns, worn to smoothness by the attrition of sand and ashes eaten with the half-cooked food. A bi-section of some of these teeth showed the dental nerve to be protected by an unusual thickness on the surface of the crown. Not one carious tooth was found among the hundreds in the mound. Many were entire in the lower jaw, the whole compactly and firmly set. In some the second set was observed; while one jaw had evident signs of a third set, a nucleus of a tooth being seen beneath the neck of a tooth of a very old jaw, whose alveolar process was gone, and the whole lower jaw ossified to a sharp edge; none showing the partial loss of teeth by caries and decay.

Some of the skulls showed evident marks of death by violence, as from the hands of the enemy in war. In one instance the flint arrowhead was seen sticking in the left parietal bone. A number of skulls were broken in, mostly at the vertex, seemingly by that rude weapon, the stone battle-ax, which was so effective on the skulls of the Spaniards in the early periods of their settlement of Florida. It is evident that sanguinary conflicts often took place between tribes of the mainland, in their disputations for those enviable islands of the sea-coast, abounding then in spontaneous productions and surrounded by fish and oysters. No remains of these, much below adult age, were found; the weak and slender frame had returned to dust. All that could be traced of their mortality was a carbonized deposit in the clean sand, with here and there a small fragment of bone.

Pursuing my investigations, and excavating farther toward the southeast face of the mound, I came upon the largest-sized stone ax I have ever seen or that had ever been found in that section of the country. Close to it was the largest and most perfect cranium of the mound, not crushed by the pressure of the earth, complete in its form, quite dry, and no sand in its cavity; together with its inferior maxillary bone, with all the teeth in the upper and lower jaws. Near by the side of this skull were the right femoris, the tibia, the humerus, ulna, and part of the radius, with a portion of the pelvis directly under the skull. All of the other bones of this large skeleton were completely or partially decayed. Contiguous to this was nearly a quart of red ocher, and quite the same quantity of what seemed to be pulverized charcoal, as materials of war-paint. Anticipating a perfect specimen in this skull, I was doomed to disappointment; for, after taking it out of the earth and setting it up, so that I could view the fleshless face of this gigantic savage, in the space of two hours it crumbled to pieces, except small portions. According to the measurement of the bones of this skeleton, its height must have been quite 7 feet.

There were three distinct rude ornaments in this mound. First, the vertebræ of a fish, painted with red ocher, and well preserved. Second, an hexagonal bead, made from the tooth of the alligator, (not painted.)

Third, the internal lamina of an oyster-shell, cut into small circular spangles, pierced with a hole in the center, and threaded with the fibrillæ of the tendon of some animal, closely strung, and painted with red ocher.

Coal was freely diffused throughout the mound, which contained but little pottery. Two stone hatchets were found, and a small stone ax, in addition to the large one described. This instrument bore evident marks of fire.

There is one large mound on the eastern end of Amelia Island, Florida, and two mounds on the central portion of Cumberland Island, Georgia, likewise most of the islands on that coast, from which could be obtained large collections of materials for the advancement of ethnological science.

ANTIQUITIES OF FLORIDA.

[Extract from the journal of John Bartram, of Philadelphia. London, 1769.]

"About noon [25th January, 1766] we landed at Mount Royal and went to an Indian tumulus, which was about 100 yards in diameter, nearly round, and near 20 feet high. Found some bones scattered on it. It must be very ancient, as live-oaks are growing upon it 3 feet in diameter. What a prodigious multitude of Indians must have labored to raise it, to what height we cannot say, as it must have settled much in such a number of years; and it is surprising where they brought the sand from, and how, as they had nothing but baskets or bowls to carry it in. There seems to be a little hollow near the adjacent level on one side, though not likely to raise such a tumulus the fiftieth part of what it is; but directly north from the tumulus is a fine straight avenue about 60 yards broad, all the surface of which has been taken off and thrown on each side, which makes a bank of about a rood wide and a foot high, more or less, as the unevenness of the ground required, for the avenue is as level as a floor from bank to bank, and continues so for about three-quarters of a mile to a pond of about one hundred yards broad and one hundred and fifty long, north and south, seemed to be an oblong square, and its banks four feet perpendicular, gradually sloping every way to the water, the depth of which we could not say, but do not imagine it deep, as the grass grows all over it; by its regularity it seems to be artificial; if so, perhaps the sand was carried from hence to raise the tumulus, as the one directly faces the other at each end of the avenue. On the south side of the tumulus I found a very large rattlesnake sunning himself; I suppose this to be his winter-quarters. Here had formerly been a large Indian town. I suppose there are fifty acres of planting ground cleared, and of middling soil, a good part of which is mixed with small shells; no doubt this large tumulus was their burying-place or sepulcher. Whether the Florida Indians buried the bones after the flesh was rotted off them, as the present southern Indians do, I cannot say."

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